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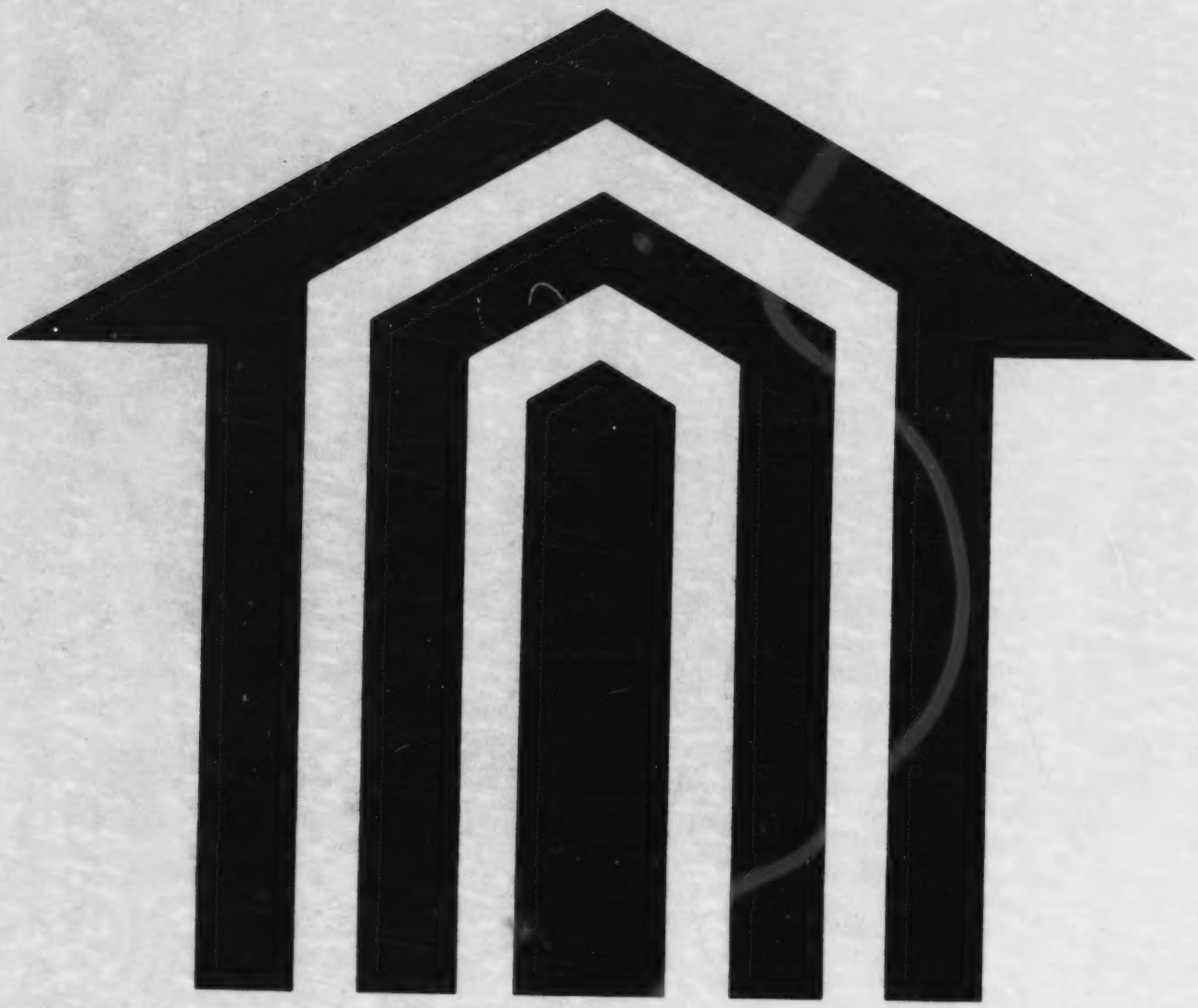
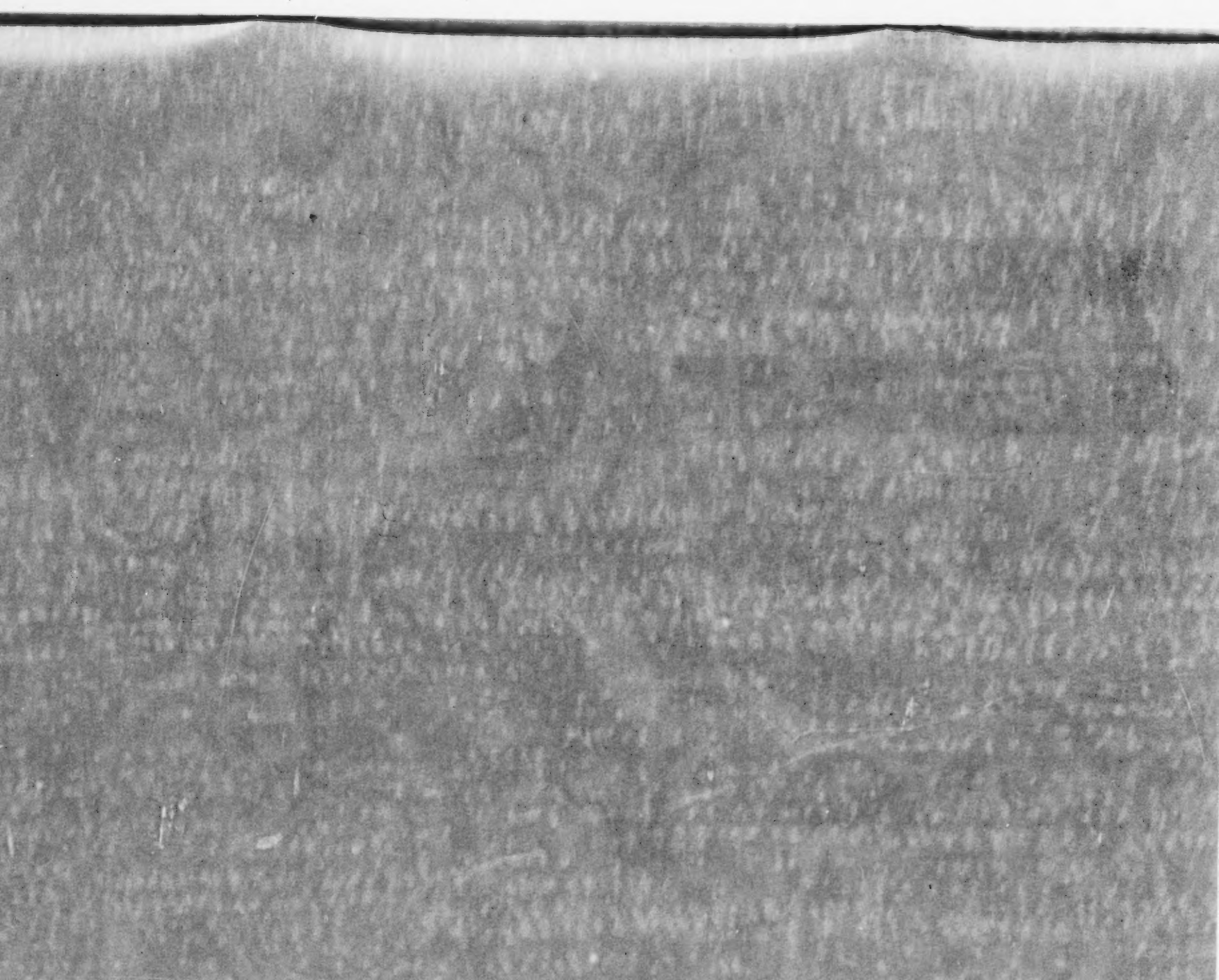
Interim Noise Assessment Guidelines





Interim Noise Assessment Guidelines

William J. Galloway
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1980

Preface

The Department of Housing and Urban Development, in its efforts to provide decent housing and a suitable living environment, is concerned with noise as a major source of environmental pollution and has issued Subpart B on Noise Abatement and Control to Part 51 of Title 24 of the Code of Federal Regulations.

The policy established by Subpart B embodies HUD objectives to make the assessment of the suitability of the noise environment at a site: (1) easy to perform; (2) uniformly applicable to different noise sources; and (3) as consistent as possible with the assessment policies of other Federal departments and agencies. In furtherance of these objectives, the Office of Policy Development and Research has sponsored research to provide site analysis techniques. These Noise Assessment Guidelines do not constitute established policy of the Department but do provide a methodology whose use is encouraged by HUD as being consistent with its objectives. The Guidelines provide a means for assessing separately the noise produced by airport, highway, and railroad operations, as well as the means for aggregating their combined effect on the overall noise environment at a site.

These guidelines are being issued for immediate use; however, the Department will review and, if necessary, amend these procedures after a reasonable period of experience. Comments on these procedures should be sent to:

U.S. Department of Housing and Urban Development
Office of Environmental Quality
Washington, D. C. 20410

This booklet has been prepared by Bolt Beranek and Newman Inc. under Contract No. H-2243R for the U.S. Department of Housing and Urban Development. It is a revision of an earlier edition published in August 1971. The contractor is solely responsible for the accuracy and completeness of the data and information contained herein.

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Introduction

These guidelines are presented as part of a continuing effort by the Department of Housing and Urban Development to provide decent housing and a suitable living environment for all Americans.

The procedures described here have been developed so that people without technical training will be able to assess the exposure of a housing site to present and future noise conditions. In this context, the site may hold only one small building, in which case the noise assessment is straightforward. Larger sites may hold larger buildings, or many buildings, and the noise level may be different at different parts of the site (or building). Assessments of the noise exposure should be made at representative locations around the site where significant noise is expected. These are designated as "Noise Assessment Locations," abbreviated NAL in the following text.

The only materials required are a map of the area, a ruler (straight edge), a protractor, a pencil, and perhaps a 100-ft tape measure. Worksheets and working figures are provided separately.

All of the information you will need can be obtained from public agencies —usually by telephone. For convenience, this information is listed at the beginning of each section under headings that indicate the most likely source. While you are obtaining this information, be sure to ask about any approved plans for future changes that may affect noise levels at the site—for example, land-use changes, changes in airport runway traffic, widening of roads, and so forth. In all evaluations, you should assess the condition that will have the most severe or most lasting effect on the use of the site.

Wherever possible, you should try to assess noise environments expected at least ten years in the future.

The degree of acceptability of the noise environment at a site is determined by the outdoor day-night average sound level (DNL) in decibels (dB). The assessment of site acceptability is presented first as an evaluation of the site's exposure to three major sources of noise—Aircraft, Roadways, and Railways. These are then combined to assess the total noise at a site. Worksheets are provided at the back of these Guidelines to use in summarizing your evaluations.

The noise environment at a site will come under one of three categories:

Acceptable - DNL not exceeding 65 decibels

- the noise exposure may be of some concern but common building constructions will make the indoor environment acceptable and the outdoor environment will be reasonably pleasant for recreation and play.

Normally Unacceptable - DNL above 65 but not exceeding 75 decibels

- the noise exposure is significantly more severe; barriers may be necessary between the site and prominent noise sources to make the outdoor environment acceptable; special building constructions may be necessary to ensure that people indoors are sufficiently protected from outdoor noise.

Unacceptable - DNL above 75 decibels

- the noise exposure at the site is so severe that the construction cost to make the indoor noise

environment acceptable may be prohibitive and the outdoor environment would still be unacceptable.

When measuring the distance from the site to any noise source, measure from the source to the nearest points on the site where buildings having noise-sensitive uses are located. These points define the Noise Assessment Locations for the site. The relevant measurement location for buildings is a point 2 meters (6.5 feet) from the facade.

If at any point during the assessment the site's exposure to noise is found Unacceptable or Normally Unacceptable, every effort should be made to improve the condition, e.g., the location of the proposed dwellings can be changed or some shielding can be provided to block the noise from that source.

Where quiet outdoor space is desired at a site, distances should be measured from the important noise sources to the outdoor area in question and the combined noise exposure should be assessed.

Frequently, the locations of dwellings have not yet been specified at the time the noise assessment of a site is made. In these instances, distances used in the noise assessment should be measured as 2 meters less than the distance from the building setback line to the major sources of noise.

Combining Sound Levels in Decibels — Worksheet A

The noise environment at a site is determined by combining the contributions of different noise sources. In these Guidelines, Workcharts are provided to estimate the contribution of aircraft, automobile, truck, and train noise to the total day-night average sound level (DNL) at a site. The DNL contributions from each source are expressed in decibels and entered on Worksheet A. The combined DNL from all the sources is the DNL for the site and is the value used to determine the acceptability of the noise environment.

Sound levels in decibels ARE NOT COMBINED BY SIMPLE ADDITION! The following table shows how to combine sound levels:

Table 1

Difference in Sound Level	Add to Larger Level
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
12	0.3
14	0.2
16	0.1
greater than 16	0

Use the table by first finding the numerical difference in sound level between two levels being combined. Entering the table with this value, find the value to be added to the larger of the two levels, add this value to the larger level to determine the total. Where more than two levels are to be combined use the same procedure to combine any two levels, then use this subtotal and combine it with any other level, and so on. Fractional numerical values may be interpolated from the table; however, the final result should be rounded to the nearest whole number.

Example 1: In performing a site evaluation, the separate DNL values for airports, road traffic, and railroads have been listed on Worksheet A as 56, 63, and 61 decibels. In order to complete the final evaluation of the site, these separate DNL values must be combined. The difference between 63 and 56 is 7; from the table you find that 0.8 should be added to 63, for a subtotal of 63.8. The difference between 63.8 and 61 is 2.8; from the table you interpolate that approximately 1.9 should be added to 63.8 for a total of 65.7 or 66 dB when rounded to whole numbers. This example shows how noise from different sources may be Acceptable, individually, at a site, but when combined, the total noise environment may exceed the Acceptable DNL limit of 65 decibels.

Aircraft — Worksheet B

Necessary Information

To evaluate a site's exposure to aircraft noise, you will need to consider all airports (civil and military) within 15 miles of the site. The information required for this evaluation is listed below under headings that indicate the most likely source. Before beginning the evaluation, you should record the following information on Worksheet B -

From the FAA Area Office or the Military Agency in charge of the airport:

- Are current DNL or NEF (Noise Exposure Forecast) contours available? Noise contours are available for almost all military airports. These contours have been developed and published as part of the Air Installation Compatible Use Zone (AICUZ) program of the Department of Defense. The contours are published normally as part of an AICUZ report. Noise contours are also available for many civil airports. When available, they are superimposed on a map with an appropriately marked scale (see Figure 1, page 6).

- Any available information about approved plans for runway changes (extensions or new runways).

From the FAA Control Tower or Airport Operations (if DNL or NEF contours are <u>not</u> available):

- The number of nighttime operations (10 p.m. - 7 a.m.)

- The number of daytime operations (7 a.m. - 10 p.m.)

- The flight paths of the major runways.

- Any available information about expected changes in airport traffic, e.g., will the number of operations increase or decrease in the next 10 or 15 years.

In making your evaluation, use the data for the heaviest air traffic condition, whether present or future.

Evaluation of Site Exposure to Aircraft Noise

If current DNL (or NEF) contours are available (as in Figure 1, page 6), locate the site on the map by referring to the marked distance scale. Obtain the DNL at the appropriate NAL on the site by interpolation between the contours on either side of the NAL. If NEF contours are used, estimate DNL by adding 35 decibels to the NEF values. Note that contours are usually provided in 5 decibel increments. (See Example 2 on page 5.) When supersonic aircraft operations are present, DNL contours are <u>required</u> for the assessment.

If DNL or NEF contours are <u>not</u> available, the DNL at a site may be estimated in several different ways.

- A handbook available from EPA (Reference 1 at the back of this Guide) can be used to calculate DNL at individual points.

- An FAA Handbook (Reference 2) can be used to estimate DNL contours for sites in general aviation airport vicinities. General aviation airports exclude commercial jet transports but may include business jets.

- A procedure for constructing approximate DNL contours for sites near commercial jet airports without supersonic aircraft is as follows:

  Determine the "effective" number of jet operations at the airport by first multiplying the number of nighttime jet operations by 10.

  Then add the number of daytime operations to obtain an effective total (see Example 3, page 8).

  On a map of the area showing the principal runways, mark the location of the site and, using the diagram and charts of Figure 3 on page 7, construct approximate DNL contours of 65, 70, and 75 dB for the major runways and flight paths most likely to affect the site, as shown in Figure 2, page 6.

Example 2: The illustration in Figure 1 at the top of page 6 shows the NALs on a map that has DNL contours. We find that NAL #1 lies between the 65 and 70 dB contours and that NAL #2 lies outside the 65 dB contour.

We find the DNL at NAL #1 by interpolation from the distances between the NAL and the 65 and 70 dB contours.

By scaling off the map, we find that the distance from the NAL, measured perpendicularly to the contours, is 800 feet to the 65 dB contour and 2400 feet to the 70 dB contour. The distance between the 65 and 70 dB contours is 2400 + 800 = 3200 feet. We find the DNL at the NAL #1 to be 65 decibels plus 800/3200 x 5 decibels = 66.3 decibels.

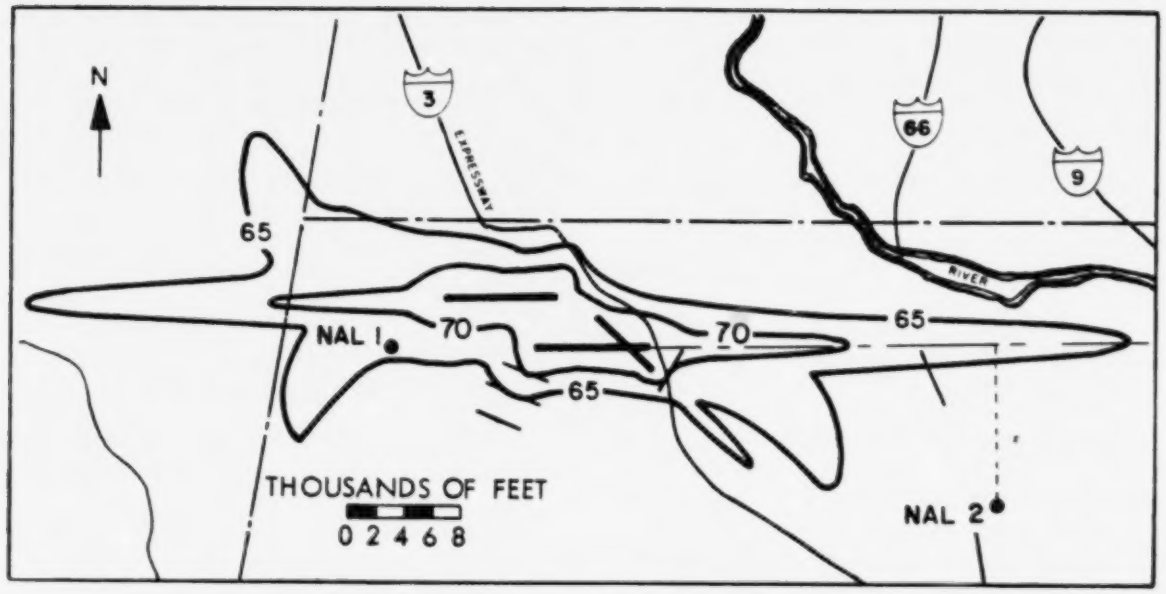


FIGURE 1. EXAMPLE OF DNL CONTOURS

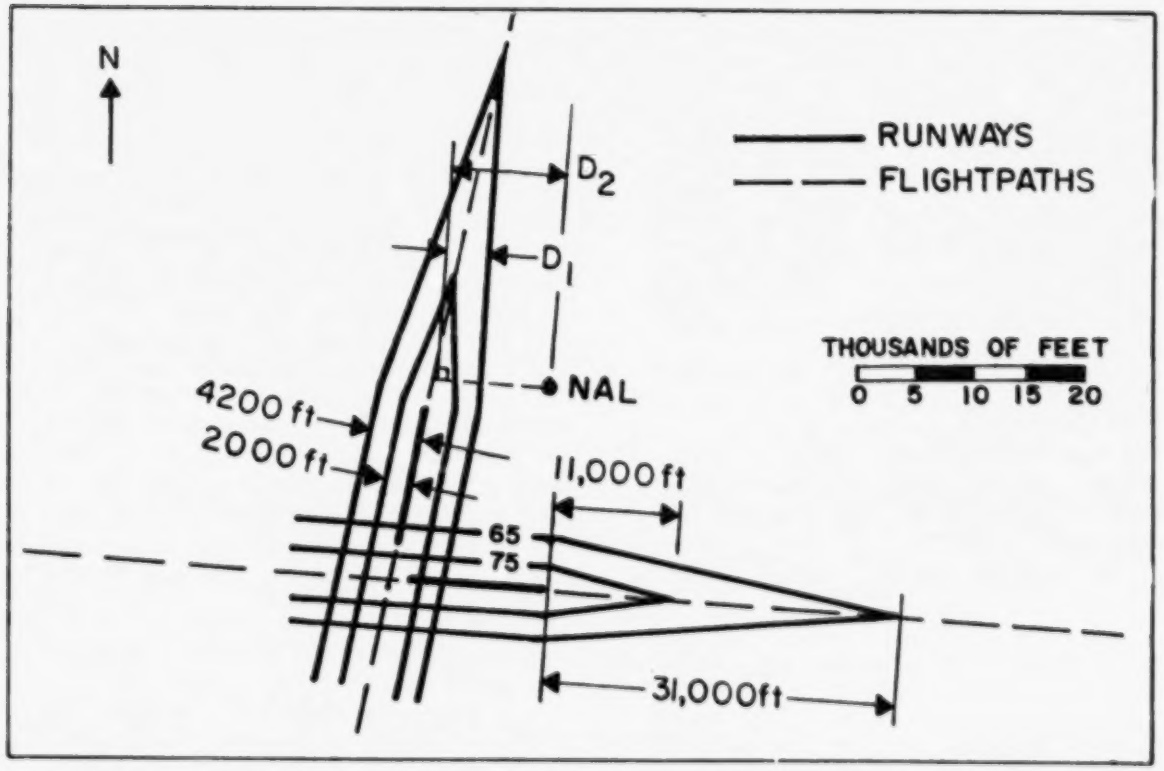
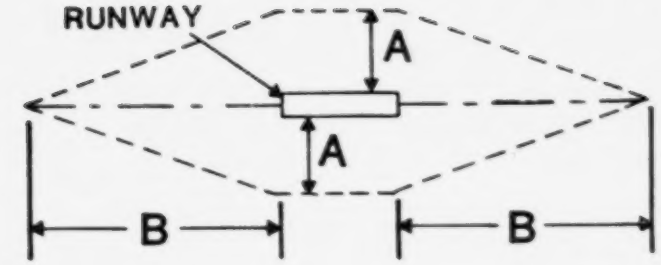


FIGURE 2. EXAMPLE OF APPROXIMATE DNL CONTOURS FOR AN AIRPORT WITH 225 EFFECTIVE NUMBER OF OPERATIONS



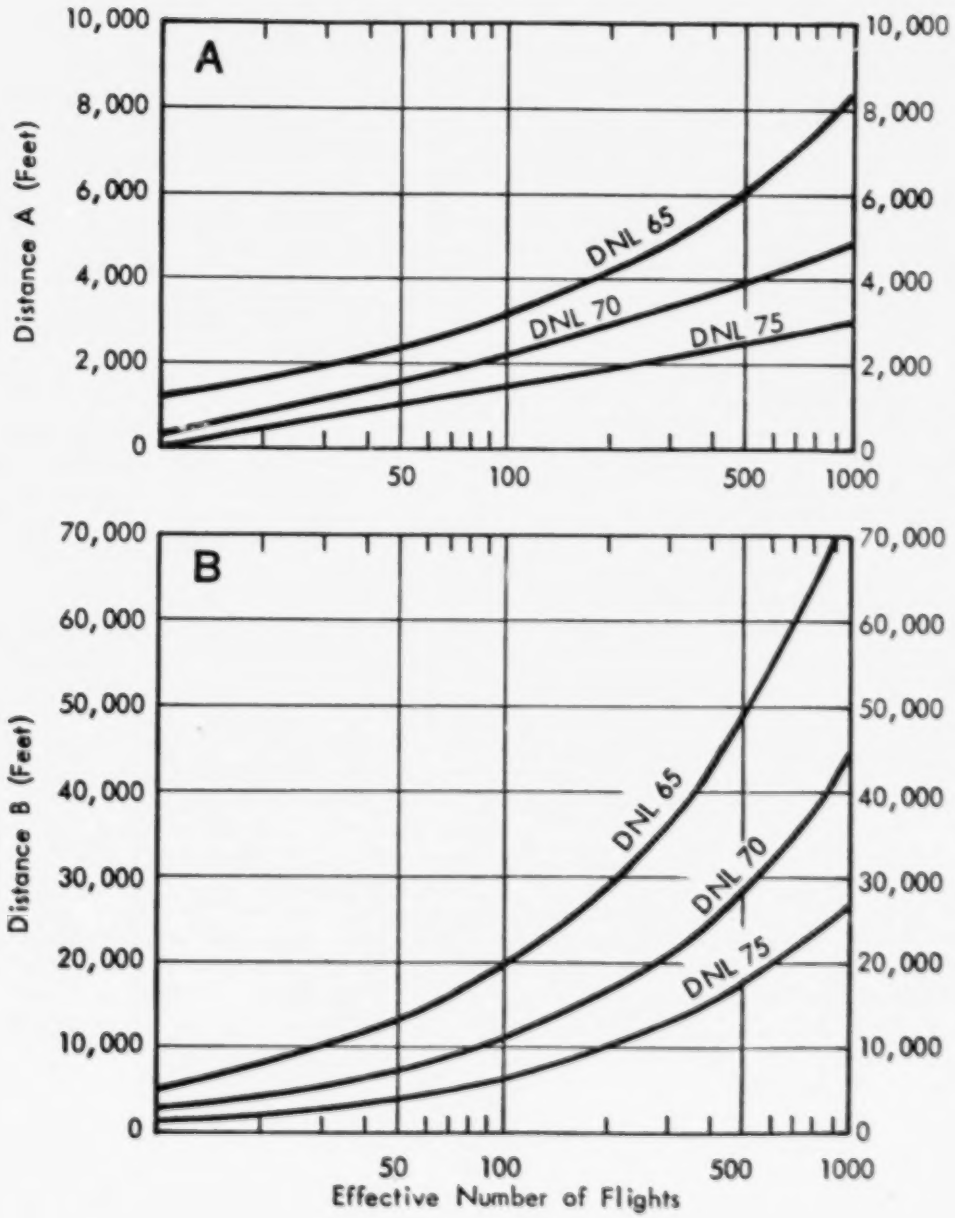


FIGURE 3. CHARTS FOR ESTIMATING DNL FOR AIRCRAFT OPERATIONS

Example 3: The illustration in Figure 2 at the bottom of page 6 shows an airport for which DNL or NEF contours are not available. The airport has 10 nighttime and 125 daytime jet operations.

To construct the approximate contours, we determine the effective number of operations as follows:

10 (nighttime) x 10 = 100

Add to this the actual number of daytime operations:

100 + 125 (daytime) = 225

To determine the distances A and B in relation to the runway (see Figure 3, page 7), enter the effective number of operations on the horizontal scales of the charts in Figure 3; read up to the DNL curves; read across the chart to the left to obtain distances A and B from the vertical scales on the charts.

We find from Figure 3, for example, that for 225 effective operations, distance A is 4200 feet for the 65 dB contour and 2000 feet for the 75 dB contour. Distance B is 31,000 feet for the 65 dB contour and 11,000 feet for the 75 dB contour.

Although a site may be Acceptable for exposure to aircraft noise, exposure to other sources of noise, when combined with the aircraft noise, may make the site not acceptable. Therefore, if necessary, values of aircraft noise exposure less than 65 dB can be estimated from Table 2. Scale the shortest distance D_2 from the site to the flight path, as in Figure 2. Scale the distance D_1 from the 65 dB contour to the flight path. Divide D_2 by D_1 and enter this value into the following table to find the approximate DNL at the site.

Table 2

D_2/D_1	DNL dB
1.00	65
1.12	64
1.26	63
1.41	62
1.58	61
1.78	60
2.00	59
2.24	58
2.51	57
2.82	56
3.16	55

Example 4a: The NAL shown in Figure 2 is outside the 65 dB contour. The distance D_2 from the NAL to the flight path is 9700 feet. The distance D_1 from the 65 dB contour to the flight path, measured perpendicularly from the contour, is 3700 feet. The ratio D_2/D_1 is 9700/3700 = 2.62. From Table 2 we find the DNL from the airport to be 56.6 dB. We do not know whether the site is Acceptable or not, however, since we must also assess the contribution of roadway and train noise to the total DNL at the site.

Example 4b: We observe that the perpendicular distance (D_2) from NAL #2 (Figure 1) to the flight path is more than 3 times the distance (D_1) from the 65 dB contour to the flight path. From Table 2 we find that the contribution of the airport to the DNL at NAL #2 is less than 55 decibels. We need not consider the airport further in accessing the noise environment at this site.

Roadways – Worksheet C

Necessary Information

To evaluate a site's exposure to roadway noise, you will need to consider all roads that might contribute to the site's noise environment; roads farther away than 1000 feet normally may be ignored. The information required for this evaluation is listed below under headings that indicate the most likely noise source.

Before beginning the evaluation, determine if roadway noise predictions already exist for roads near the site. Also try to obtain all available information about approved plans for roadway changes (e.g., widening existing roads or building new roads) and about expected changes in road traffic (e.g., will the traffic on this road increase or decrease in the next 10 or 15 years).

If this information exists, it should be available from the City (County) Director of Traffic. If not, record the following information on page 1 of Worksheet C –

- The distances from the NALs for the site to the near edge of the nearest lane and the far edge of the farthest lane.
- Distance to stop signs.
- Road gradient, if 2 percent or greater.
- Average speed.
- The total number of automobiles for both directions during an average 24-hour day. Traffic engineers refer to this as ADT (or sometimes AADT, meaning Annual Average Daily Traffic).

he number of trucks during an verage 24-hour day in each irection.

f possible, separate trucks into heavy trucks"—those weighing more han 26,000 pounds with three or ore axles—and "medium trucks"—hose between 10,000 and 26,000 ounds. (Each medium truck is ounted as equal to 10 automo-iles.) Trucks under 10,000 pounds re counted as automobiles. Count uses capable of carrying more than 5 seated passengers as "heavy" rucks—others, as "medium" rucks.

Note: If the road has a gradient f 2 percent or more, record the umbers for uphill and downhill raffic separately since these fig-res will be needed later; other-ise, simply record the total num-er of trucks. Most often you will ave to assume that the uphill and ownhill traffic are equally plit.

he fraction of ADT that occurs uring nighttime (10 p.m. to 7 .m.). If this is unknown, assume .15 for both trucks and autos.

aluation of Site Exposure Roadway Noise

ffic surveys show that the amount roadway noise depends on the per-ntage of trucks in the total traf-volume. To account for this fect, you must evaluate automobile truck traffic separately and then bine the results.

noise environment at each site to traffic noise is determined by lizing a series of Workcharts to fine the contribution of automo-es and trucks from one or more roads at that site. Each noise source yields a separate DNL value.

Workchart 1 provides a graph for assessing a site with respect to the noise from automobiles, light and medium trucks; Workchart 2 provides a similar graph for assessment of heavy truck noise. These values are combined for each road affecting the noise environment at the site to obtain the total contribution of roadway noise. Remember, the noise from aircraft and railways must also be considered before determining the suitability of this site's noise environment.

Effective Distance

Before proceeding with these separate evaluations, however, determine the "effective distance" to each road from the dwelling or outdoor residential activity (the NALs for the site) by averaging the distances to the nearest edge of the nearest lane and to the farthest edge of the farthest lane of traffic. (See Example 5, page 12, and Figure 4, page 13.)

Note: For roads with the same number of lanes in both directions, the effective distance is the distance to the center of the roadway (or median strip, if present).

Automobile Traffic

Workchart 1 was derived with the following assumptions:

- There is line-of-sight exposure from the site to the road; i.e., there is no barrier which effectively shields the site from the noise of the road.
- There is no stop sign within 600 feet of the site; traffic lights do

not count because there is usually traffic moving on one street or the other.

- The average automobile traffic speed is 55 mph.

- The nighttime fraction of ADT is 0.15.

If each road meets these four conditions, proceed to Workchart 1 for the evaluation. Enter the horizontal axis with the effective distance from the roadway to the NAL; draw a vertical line upward from this point. Enter the vertical axis with the effective automobile ADT; draw a horizontal line across from this point. (The "effective" automobile ADT is the sum of automobile, light truck, and 10 times the number of medium trucks in a 24-hour day.) Read the DNL value from Workchart 1 where the vertical and horizontal lines intersect. Record this value in column 16, Worksheet C.

BUT:

If any of the four conditions is different, make the necessary adjustments (on page 2, Worksheet C) listed below and then use Workchart 1 for the final evaluation.

First, a few general words about adjustments as they are applied in these Guidelines. Each Workchart has been derived for a baseline condition which is often found in practical cases. Where conditions differ from the baseline, they are accounted for by a series of one or more adjustment factors.

The adjustment factors are used as multipliers times the average number of vehicles operating during a 24-hour day. If more than one adjustment is required, it is not necessary that each be multiplied times the basic traffic flow separately; all adjustment factors are multiplied together, and then multiplied times the original traffic flow data. This will become clearer as you examine the Worksheets at the back of these Guidelines and work through the examples. After you have become familiar with the Guidelines, you will be able to work examples directly from the Worksheets without referring back to the text. To simplify your work, all the adjustment factors are summarized at the back of these Guidelines.

Adjustments for Automobile Traffic

Stop-and-Go Traffic:

If there is a stop sign (not a traffic signal) within 600 feet of the NAL so that the flow of traffic is completely interrupted on the road under consideration, find the stop-and-go adjustment factor for automobiles from Table 3. Enter this value in column 9 on Worksheet C.

Table 3

Distance from NAL to Stop Sign feet	Automobile Stop-and-Go Adjustment Factor
0	0.10
100	0.25
200	0.40
300	0.55
400	0.70
500	0.85
600	1.00

Average Traffic Speed:

If the average automobile speed is other than 55 mph, enter the appropriate adjustment from Table 4 in column 10 of Worksheet C.

Table 4

Average Traffic Speed	Auto Speed Adjustment Factor
20 (mph)	0.13
25	0.21
30	0.30
35	0.40
40	0.53
45	0.67
50	0.83
55	1.00
60	1.19
65	1.40
70	1.62

Nighttime Adjustment:

DNL values are affected by the proportion of traffic volume that occurs during "daytime" (7 a.m. to 10 p.m.) and "nighttime" (10 p.m. to 7 a.m.). The graph on Workchart 1 assumes that 15 percent of the total ADT occurs during nighttime. If a different proportion of the traffic occurs at night, find the appropriate nighttime adjustment factor from Table 5. Record your answer in column 11 of Worksheet C.

Table 5

Nighttime Fraction of ADT	Nighttime Adjustment Factor
0	0.43
0.01	0.46
0.02	0.50
0.05	0.62
0.10	0.81
0.15	1.00
0.20	1.19
0.25	1.38
0.30	1.57
0.35	1.77
0.40	1.96
0.45	2.15
0.50	2.34

Once you have selected all the appropriate adjustment factors and entered them on page 2 of Worksheet C, multiply all the factors together, then multiply by the automobile ADT (column 12) for 24 hours, found on page 1 of Worksheet C. The resulting adjusted ADT should be entered in column 13. This is the ADT value to be used, in conjunction with the effective distance from the NAL to the road, to find the DNL value from Workchart 1. Enter this DNL value in column 14 of Worksheet C. Remember this is the DNL from automobile (as well as light and medium truck) noise; you must still find the DNL contribution from heavy truck noise in order to obtain the total DNL produced by the roadway you are assessing.

Attenuation of Noise by Barriers:

This adjustment reduces the noise produced by automobiles and trucks on the same road. Instructions for this adjustment appear after the noise assessment for truck traffic below.

Example 5: The site shown in Figure 4 is exposed to noise from three major roads: Road #1 has four lanes, each 12 feet wide, and a 30-foot wide median strip which accommodates a railroad track. Road #2 has four lanes, each 12 feet wide. Road #3 has six lanes, each 15 feet wide, and a median strip 30 feet wide.

The distance from NAL #1 to the near edge of Road #1 is 300 feet. The distance to the far edge of Road #1 is 300 feet, plus the number of lanes times the lane width, plus the width of the median strip. Thus, the distance to the farthest edge of the road is:

$$300 + (4 \times 12) + 30 = 378 \text{ ft}$$

The effective distance is

$$\frac{378 + 300}{2} = 339 \text{ ft}$$

This is the value to be entered on line 1c of Worksheet C. The effective distances from the appropriate NALs to Road #2 and Road #3 are found by the same method.

The distances shown in Figure 4 will be used for all roadway examples in this booklet.

Example 6: Road #1 meets the four conditions that allow for an immediate evaluation. In obtaining the information necessary for this evaluation, it was found that the automobile ADT is 18,000 vehicles (Line 5c of Worksheet C). On Workchart 1 we locate on the vertical scale the point representing 18,000 and on the horizontal scale the point representing 339 feet (see Figure 5). (Note that we must estimate the location of this point.) Using a straight-edge we draw lines to connect these two values and find that the site's exposure to automobile noise from this road is a DNL of 58 dB, as read from the scale at the top of the graph.

Example 7: Road #2 has a stop sign at 390 feet from NAL #2. The automobile ADT is reported as being 32,500 vehicles (line 5c of Worksheet C). From Table 3 we interpolate between

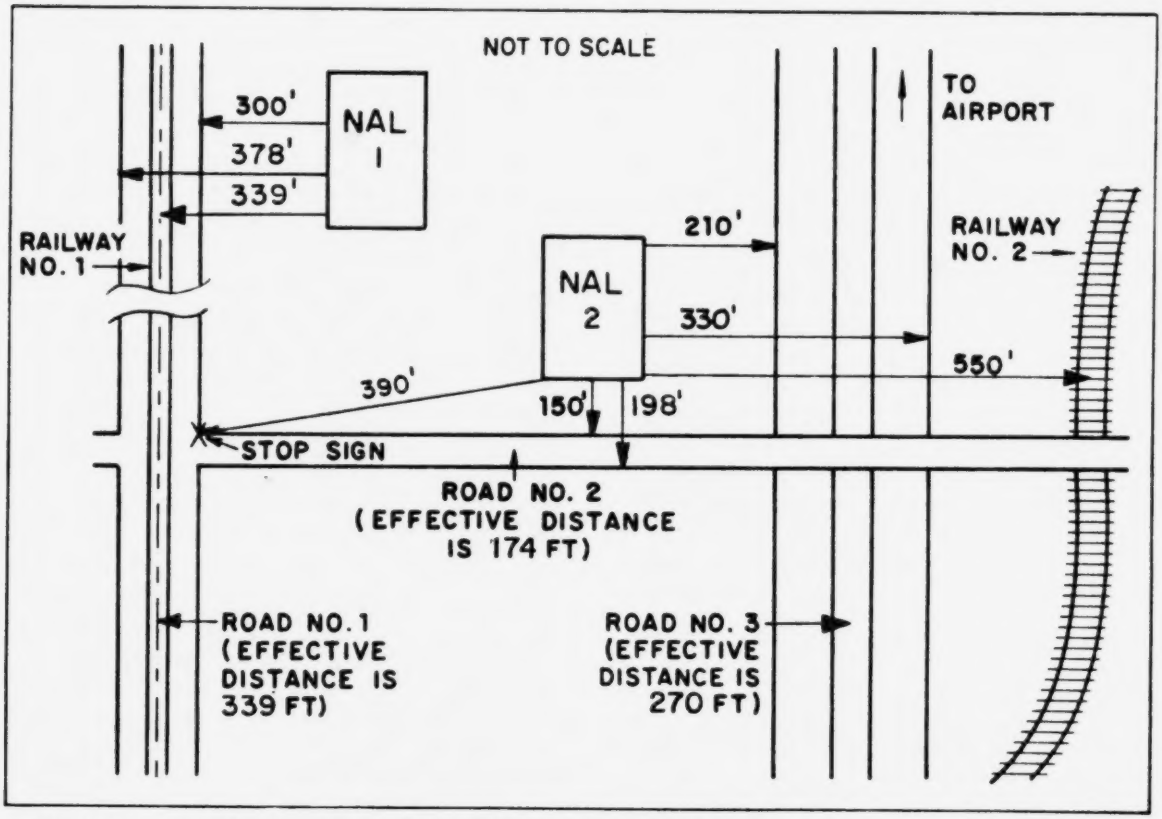


FIGURE 4. PLAN VIEW OF SITE SHOWING HOW DISTANCES SHOULD BE MEASURED FROM THE NOISE ASSESSMENT LOCATION (NAL) OF THE DWELLING NEAREST TO THE SOURCE

300 and 400 feet to find the adjustment factor for stop-and-go traffic to be 0.69. The adjusted traffic ADT is

0.69 x 32,500 = 22,425 vehicles per day

and with an effective distance of 174 feet from NAL #2, we find from Workchart 1 that the approximate value of DNL is 64 dB.

Example 8: Suppose that the stop sign on Road #2 were replaced by a traffic signal for which no stop-and-go adjustment is made and that the ADT increases to 75,000 vehicles. In addition, assume that the average speed is 45 mph instead of 55 mph. You adjust the new automobile ADT of 75,000 vehicles by the Auto Speed Adjustment Factor from Table 4

0.67 x 75,000 = 50,250 vehicles

and at an effective distance of 174 feet find from Workchart 1 that the approximate value of DNL is 67 dB.

Example 9a: Road #3 is a limited access highway with no stop signs and the average speed is 55 mph. Current traffic data indicate an automobile ADT of 40,000 vehicles of which 15 percent occurs during nighttime hours (10 p.m. to 7 a.m.). With an effective distance of 270 feet to NAL #2, Workchart 1 is used to show that the DNL for existing automobile traffic is between 63 and 64 dB. Round off to 64 dB.

Example 9b: However, traffic projections estimate that in 10 years the ADT will increase to 100,000 vehicles at an average speed of 55 mph and nighttime usage will increase to 25 percent. For future traffic, you must adjust the future ADT of 100,000 for the effect of increased nighttime

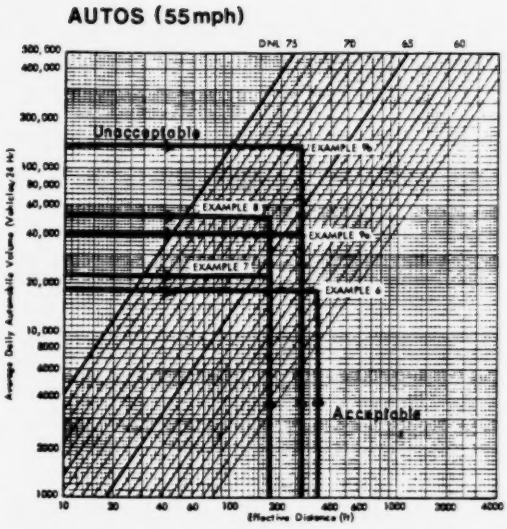


FIGURE 6. USE OF WORKCHART 1 TO EVALUATE AUTOMOBILE TRAFFIC NOISE

use. From Table 5, you find an adjustment factor of 1.38. The adjusted ADT is

1.38 x 100,000 = 138,000

and at an effective distance of 270 feet you find from Workchart 1 that the DNL will increase to 69 dB; therefore, provision for extra noise control measures should be explored. We will examine in Example 13 the effect of terrain as a shielding barrier that provides sound attenuation.

Truck Traffic

Wherever possible, separate the average daily volume of trucks into heavy trucks (more than 26,000 pounds vehicle weight and three or more axles); medium trucks (less than 26,000 pounds but greater than 10,000 pounds; light trucks (counted as if they are automobiles). You should already have accounted for medium and light trucks in your automobile

evaluation. Do not forget buses that can carry more than 15 seated passengers are counted as heavy trucks. Heavy trucks (including buses) must be analyzed separately because they have quite different noise characteristics. If it is not possible to separate the trucks into those that are heavy and those that are not, treat all trucks as though they are "heavy."

Workchart 2, which is used to evaluate the site's exposure to heavy truck noise, was derived with the following assumptions:

- There is line-of-sight exposure from the site to the road; i.e., there is no barrier which effectively shields the site from the road noise.
- The road gradient is less than 2 percent.
- There is no stop sign (traffic signals are permissible) within 600 feet of the site.
- The average truck traffic speed is 55 mph.
- The nighttime fraction of ADT is 0.15.

If the road meets these five conditions, proceed to Workchart 2 for an immediate evaluation of the site's exposure to heavy truck noise from that road.

BUT:

If any of the conditions is different, make the necessary adjustment(s) listed below and then use Workchart 2 for the evaluation.

Adjustments for Heavy Trucks

Road Gradient:

If there is a gradient of 2 percent or more, find the appropriate adjustment factor, for heavy trucks going uphill only, as shown in Table 6. List this factor in column 17 of Worksheet C.

Table 6

Percent of Gradient	Adjustment Factor
2	1.4
3	1.7
4	2.0
5	2.3
6 or more	2.5

Average Traffic Speed:

Make this adjustment if the average speed differs from 55 mph. If the average truck speed differs with direction, treat the uphill and downhill traffic separately. Select the appropriate adjustment factors from Table 7 below, entering them in column 18 of Worksheet C.

Table 7

Average Traffic Speed (mph)	Heavy Truck Speed Adjustment Factor
50 or less	0.81
55	1.00
60	1.17
65	1.38

Once you have found the speed adjustment factor, you can combine the uphill and downhill traffic. For uphill traffic, multiply the gradient factor times the speed adjustment factor times uphill traffic volume (truck ADT column 19) (assuming

one-half the total 24-hour average number of trucks unless specific information to the contrary exists), entering the product in column 20. Multiply the speed adjustment factor for downhill traffic times the downhill traffic volume (truck ADT/2 column 19). Add the values for uphill and downhill traffic, entering this sum in column 21. You may now complete the assessment of heavy truck noise without regard to uphill and downhill traffic separation.

Stop-and-Go Traffic:

If there is a stop sign (remember, not a traffic signal) within 600 feet of an NAL for the site on the road being assessed, find the adjustment factor determined according to Table 8. Enter in column 22 of Worksheet C.

Table 8

Heavy Truck Traffic Volume per Day	Heavy Truck Stop-and-Go Adjustment Factor
Less than 1200	1.8
1201 to 2400	2.0
2401 to 4800	2.3
4801 to 9600	2.8
9601 to 19,200	3.8
More than 19,200	4.5

Nighttime Adjustment

After all the above adjustments are made, do not forget to adjust for nighttime operations if they are not 15 percent of the total ADT, using the factors obtained from Table 5 just as for automobiles. Enter this value in column 23 of Worksheet C.

At this point, multiply the adjustment factors for nighttime and stop-and-go traffic times the heavy truck traffic volume in column 21 to find the adjusted heavy truck ADT, entering the product in column 24. Use this value and the effective distance from the NAL to the road to find the truck DNL from Workchart 2, entering your answer in column 25 of Worksheet C. If no shielding barriers are to be considered, combine the DNL from heavy trucks with the DNL from automobiles (column 14). The result is the DNL from the road being assessed and should be entered on Worksheet C.

BUT:

If a shielding barrier is to be considered for the site, make the analysis described below separately for automobiles and then for heavy trucks before combining the DNL values. This step is necessary since barriers are far more effective for automobiles than for heavy trucks. Once you have found the amount of attenuation provided by the barrier for automobiles, enter it in column 15. Find the value of barrier attenuation for heavy trucks and enter it in column 25. Subtract these attenuation values from the DNL values obtained previously (column 14 and 24), entering the reduced DNL values in the appropriate columns 16 and 27. Combine the automobile and heavy truck DNL values, reduced by the attenuation provided by the barrier, to find the final DNL produced by the roadway at the site.

Remember to combine the contributions to DNL of all roads that affect the noise environment at each NAL for the site to obtain the total DNL from all roadways. Enter this DNL on both Worksheet C and the summary Worksheet A.

Example 10: Road #1 on Figure 4 meets the four conditions that allow for an immediate evaluation. The ADT for heavy truck flow is 1200 vehicles. With an effective distance of 339 feet, Workchart 2 shows that the exposure to truck noise from this road is a DNL of 63 dB at NAL #1.

Example 11: Road #2 has a stop sign at 390 feet from NAL #2. There is also a road gradient of 4 percent. No heavy trucks are allowed on this road, but a schedule shows an average of 12 large buses pass along the road per hour between 7 a.m. and 10 p.m., although no buses are scheduled during the remaining nighttime period. The buses are equally divided in each direction along the road. (Remember large buses, those that carry over 15 seated passengers, count as heavy trucks.)

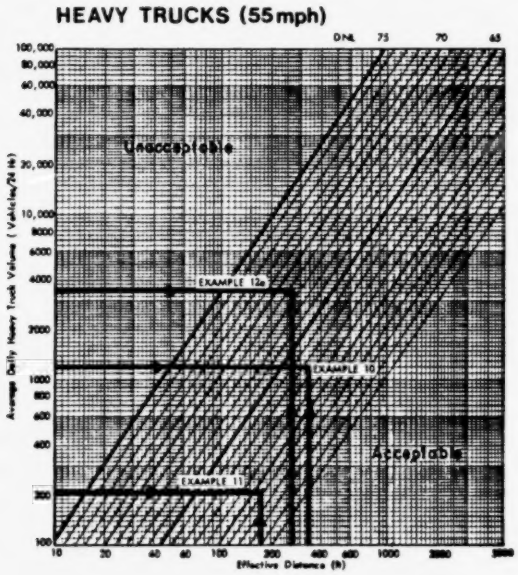


FIGURE 6. USE OF WORKCHART 2 TO EVALUATE HEAVY TRUCK NOISE

We find the ADT for the "heavy trucks" (the buses in this case) by multiplying the average number of vehicles per hour by the number of hours between 7 a.m. and 10 p.m. That is, 12 x 15 = 180, or 90 vehicles in each direction. We find from Table 6 that the gradient adjustment factor for uphill traffic is 2.0. We find the truck volume adjusted for gradient is

uphill:	*90 x 2.0 =*	*180*
downhill:	*=*	*90*
total (column 21)		*270 vehicles*

From Table 8, we find the adjustment factor for stop-and-go traffic to be 1.8.

We also remember that we have buses in the nighttime period and find the factor in Table 5 on page 12 for zero nighttime operations to be 0.43.

Our final adjusted ADT is (column 24)

$$1.8 \times 0.43 \times 270 = 209 \text{ vehicles}$$

From Workchart 2, with an effective distance of 174 feet, we find a DNL of 59 dB.

Example 12a: Road #3 is a depressed highway and the profile shields all residential levels of the housing from line of sight to the traffic. The average truck speed is 50 mph. The ADT for heavy trucks is 4400 vehicles. We adjust for average speed (from Table 7)

$$4400 \times 0.81 = 3564$$

and find from Workchart 2 that, with an effective distance of 270 feet, the DNL from truck noise would be 69 dB if no barrier existed. We proceed to analyze the barrier attenuation.

Attenuation of Noise by Barriers

Noise barriers are useful for shielding sensitive locations from ground level noise sources. For example, a barrier may be the best way to deal with housing sites at which the noise exposure is not acceptable because of nearby roadway traffic.

A barrier may be formed by the road profile, by a solid wall or embankment, by a continuous row of noise-insensitive buildings, or by the terrain itself. To be an effective shield, however, the barrier must block all residential levels from line of sight to the road; it must not have any gaps that would allow noise to leak through.

Some Preliminary Matters:

In evaluating noise barrier performance, you will be working with different kinds of "distances" between the sound source, the observer, and the barrier.

Actual Distance - the existing distance that would be measured using a tape measure with no corrections or adjustments. This may mean one of two things, depending on the application; either the -

slant distance - the actual distance, measured along the line of sight between two points; or the

map distance - the actual distance, measured on a horizontal plane, between the two points, as on a map or on the project plan.

For an observer high in an apartment tower, the slant distance to the road may be much longer than the map distance.

Barrier effectiveness is expressed in terms of noise attenuation in decibels (dB), determined with the aid of Workchart 6. This numerical value is subtracted from the previously calculated DNL in order to find the resultant DNL at the Noise Assessment Location.

Note: A noise barrier can be considered as a means of protecting a site from noise even if it cannot be made long enough, or cannot "wrap around" the site, to shield from view practically all of the source of noise at every sensitive location on the site. It must be recognized, however, that such a barrier is much less effective than an ideal barrier (see Workchart 7 and Step 6 below).

Barriers of reasonable height cannot be expected to protect housing more than a few stories above ground level. Barriers will generally protect the ground and the first two or three floors, but not the higher floors. If there are to be frequently occupied balconies on the upper levels, one solution is to move the building farther from the noise source and face the sensitive areas away from the noise.

Steps to Evaluate a Barrier

1. For the observer's position, use the mid-height of the highest residential level. For the source position, use the following heights (see Figure 7):

   autos, medium trucks, railway cars—the road or railway surface height

   heavy trucks—8 feet above the road surface

diesel locomotives or trains using horns or whistles at grade crossings—15 feet above the rails.

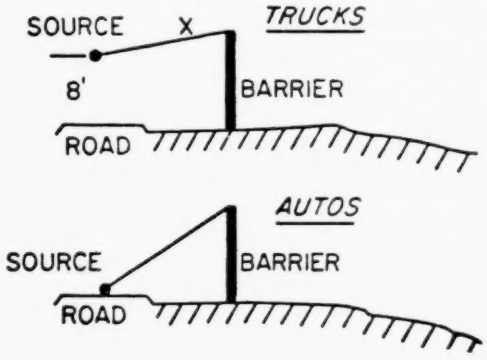


FIGURE 7. SOURCE HEIGHTS TO BE USED IN ROADWAY BARRIER DESIGNS

Get accurate values for the following quantities: h, the shortest distance from the barrier top to the line of sight from source to observer (feet); R and D, the slant distances along the line of sight from the barrier to the source and observer, respectively (see Figure 8).

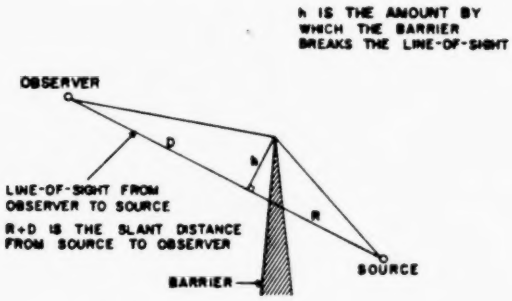


FIGURE 8. GENERALIZED GEOMETRY OF ACOUSTICAL BARRIER

Specifically, R and D are the two segments into which h breaks the line of sight. Note that h is <u>not</u> the height of the barrier above the ground but the distance from the barrier top to the line of sight.

2. Enter at the top of Workchart 6 with the value of h on the left-hand scale; move right to intersect the curve corresponding to R (or D, whichever is <u>smaller</u>).

3. Move down to intersect the curve corresponding to the value of D/R (or R/D), whichever is <u>smaller</u>.

4. Move right to intersect the vertical scale in order to find the barrier shielding A in decibels.

5. Interruption of the line of sight with a barrier between the noise source and an observer reduces the amount of sound attenuation provided by the ground. Find the amount of this loss B from the table on Workchart 6 by entering the table with the value of D/R obtained in Step 3. Find the barrier attenuation S corresponding to an ideal barrier that completely hides the noise source from view by subtracting B from the value of A obtained in Step 4.

6. If the barrier exists along only a part of the road so that unshielded sections of the road would be visible from the site, the barrier is less effective than an ideal barrier. On a plan view of the site, locate the two ends of the barrier and draw lines from these points to the Noise Assessement Location. Use a protractor to measure the angle formed at the NAL by the two lines. Enter the horizontal

scale of Workchart 7 with the values of this angle; read up to the curve having the value of S determined from Step 5 (interpolating if necessary); read left across the vertical scale labeled "actual barrier performance" to find the value of FS to use for the actual barrier in question.

7. Subtract the barrier attenuation S (or FS if adjusted for finite barrier length according to Workchart 7) from the value of DNL previously determined to re-evaluate the site with the noise barrier in place.

Example 12b: Refer to Figure 9.

Six stories are planned for the housing where the site has an elevation of 130 feet. The effective elevation for the highest story is found by multiplying the number of stories by 10 feet, adding the site elevation, and subtracting 5 feet.

(6 x 10) + 130 - 5 = 185 feet

The barrier, which in this case is formed by the road profile, has no "height" other than the elevation of the natural terrain above the noise sources traveling on the roadway. The important dimensions are indicated in Figure 9.

Some people with technical background will be able to fit the geometric diagram to the site situation readily, working from the project drawings and a scratch sheet.

But if you are not confident of your geometry, a step-by-step Workchart 5 gets you the values of R, D, and h from the map distances and elevations of the site. We illustrate that procedure in this example.

First, enter the elevations of the source S, the observer O, and the top of the barrier H, as well as the map distances from the barrier to the source D' and observer R', at the top right of Workchart 5. Then, follow the steps on that Workchart to derive the values of h, R, and D that are needed in using Workchart 6.

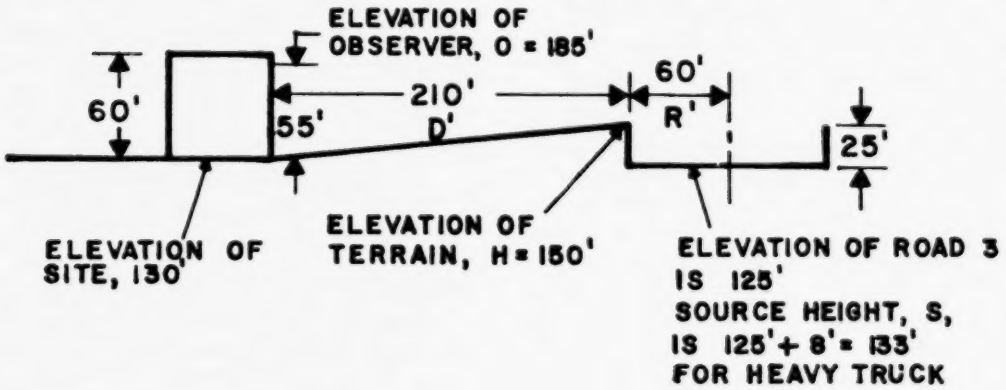


FIGURE 9. DETAIL OF SITE SHOWING MEASUREMENTS NECESSARY FOR A BARRIER ADJUSTMENT

Entering Workchart 6 at the upper left with the value of h (5.5 feet), we move horizontally to the right until we meet the value of R or D, whichever is smaller: in this example, R = 62 feet. From that point we drop vertically downward until we meet the value of R/D or D/R, whichever is smaller: in this case, R/D = 0.29. From that point, move horizontally to the right to find the value for A = 9 dB. Entering the table for determining loss of ground attenuation effect due to the barrier with D/R of 3.5, the reduction in attenuation B is found to be 3 dB. Subtracting 3 dB from 9 dB provides a net attenuation of 6 dB. With 6 dB of attenuation, the original DNL of 69 dB (Example 12a) is reduced to 63 dB.

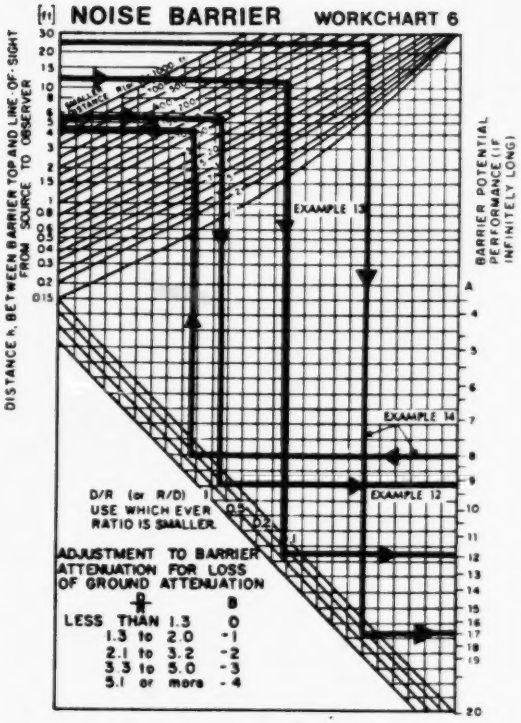

NOISE BARRIER WORKCHART 6
DISTANCE h, BETWEEN BARRIER TOP AND LINE-OF-SIGHT FROM SOURCE TO OBSERVER
BARRIER POTENTIAL PERFORMANCE (IF INFINITELY LONG)
EXAMPLE 13
EXAMPLE 14
EXAMPLE 12
D/R (or R/D) USE WHICH EVER RATIO IS SMALLER
ADJUSTMENT TO BARRIER ATTENUATION FOR LOSS OF GROUND ATTENUATION
D/R B
LESS THAN 1.3 0
1.3 to 2.0 -1
2.1 to 3.2 -2
3.3 to 5.0 -3
5.1 or more -4

FIGURE 11. USE OF WORKCHART 6 TO EVALUATE BARRIER IN EXAMPLES 11 AND 13

NOISE BARRIER

WORKCHART 5

TO FIND R, D AND h FROM SITE ELEVATIONS AND DISTANCES

H = 150 R' = 60
S = 139 D' = 210
O = 185

Fill out the following worksheet (all quantities are in feet):

1.	Elevation of barrier top minus elevation of source	[H 150]	− [S 139]	= [11]	
2.	Elevation of observer minus elevation of source	[O 185]	− [S 139]	= [46]	
3.	Map distance between source and observer (R' + D')			[D' 210]	
4.	Map distance between barrier and source (R')			[R' 60]	
5.	Line 2 divided by line 3	[46]	÷ [D' 210]	= [0.22]	
6.	Square the quantity on line 5 (i.e., multiply it by itself); always positive	[0.22]	× [0.22]	= [0.05]	
7.	40% of line 6	[0.4]	× [0.05]	= [0.02]	
8.	One minus line 7	[1.0]	− [0.02]	= [0.98]	
9.	Line 5 times line 4 (will be negative if line 2 is negative)	[0.22]	× [R' 60]	= [13]	
10.	Line 1 minus line 9	[11]	− [13]	= [24]	
11.	Line 10 times line 8	[24]	× [0.98]	= [23.5]	= h
12.	Line 5 times line 10	[0.22]	× [24]	= [5.3]	
13.	Line 4 divided by line 8	[R' 60]	÷ [0.98]	= [61]	
14.	Line 13 plus line 12	[61]	+ [5.3]	= [66]	= R
15.	Line 3 minus line 4	[D' 210]	− [R' 60]	= [150]	
16.	Line 15 divided by line 8	[150]	÷ [0.98]	= [153]	
17.	Line 16 minus line 12	[153]	− [5.3]	= [147]	= D

FIGURE 10. USE OF WORKCHART 6 TO DETERMINE BARRIER DIMENSIONS IN EXAMPLE 12b

Example 13: An alternative approach, which is somewhat more direct, is illustrated here for the noise of automobiles on Road #3.

A preliminary step is to make an accurately-scaled sketch, for the site in question, of the general geometry introduced on page 20. It will include the positions of the source (this time at the road surface), the observer, and the top of the barrier, and will show the distance h, R, and D. Such a sketch is shown superimposed on the profile of the road and its neighborhood in Figure 12.

If we carefully scale the dimensions directly from this sketch, we find the following values for h, R, and D:

$R = 63$ *feet*

$R/D = 0.3$

$D = 214$ *feet*

$h = 11$ *feet*

The barrier attenuation is found, by entering Workchart 6 with these values, to be A = 12 dB. It is larger than that found above for trucks because the noise source is lower and is, therefore, better shielded by the barrier. The loss from ground attenuation is again B = 3 dB, for a net attenuation of 12 - 3 = 9 dB. In Example 9b, we found that the DNL for the projected traffic volume of 100,000 vehicles per day was 69 dB if no consideration was given the shielding provided by the terrain. Subtracting the 9 dB attenuation from 69, we find the partial DNL for automobiles is 60 dB.

In order to find the combined truck and automobile noise for Road #3, we combine the 63 dB of truck noise with the 60 dB of automobile noise using Table 1. We find that 1.8 should be added to 63 dB, for a combined DNL of 64.8 dB, or 65 dB when rounded to the nearest whole number.

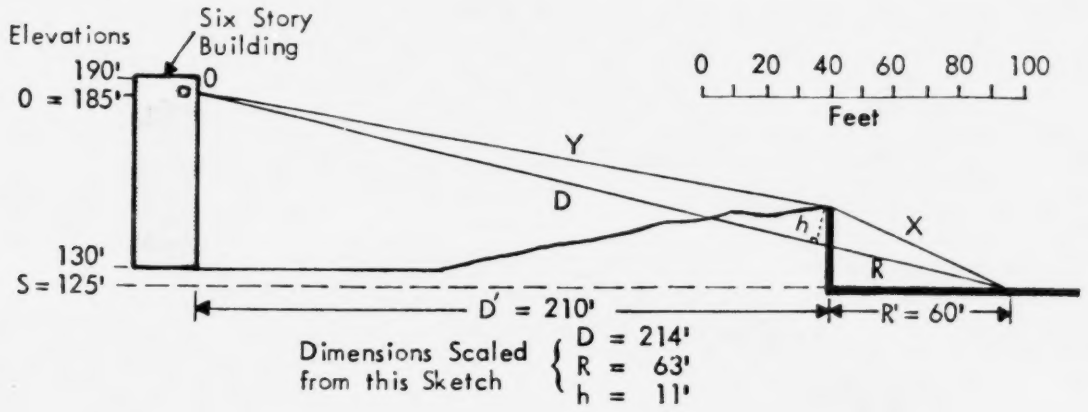


FIGURE 12. SKETCH SHOWING DIMENSIONS FOR EXAMPLE 13

Example 14: Where no natural barrier exists, Workchart 6 can be used in reverse to estimate the height of a barrier needed to obtain a required attenuation. In example 9b we found that, without any attenuation from terrain or a barrier, the automobile traffic produced a DNL of 69 dB, and in Example 12a the heavy truck traffic produced a DNL of 69 dB. When combined, the total DNL is 72 dB. Suppose the terrain were not rising between NAL and Road #3, as shown in Figure 12, but instead was level between the NAL and the edge of the road, as shown in Figure 13. We want to find out how high a wall would be required at the edge of the road to reduce the combined truck and automobile noise to less than 65 dB. We have found in the previous examples that a barrier of a given height will provide more attenuation for automobiles than it will for trucks. As a first step in our analysis, we will find the height of a wall that will just reduce the truck noise to below 65 dB, say 64 dB, and then find out whether the additional attenuation it provides for automobile noise will be sufficient to reduce the combined truck and automobile noise to less than 65 dB. We begin by finding the height of wall that will provide 5 dB attenuation for truck noise.

We estimate that the ratio of R/D is about the same as R'/D', the ratio of horizontal distance in Figure 13, which is equal to 0.29. Before entering Workchart 6, we find from the loss of ground attenuation table that for D/R = 3.4 we will lose 3 dB attenuation from an ideal barrier. In order to have a net attenuation of 5 dB, we must have an ideal barrier that provides 5 + 3 = 8 dB attenuation.

Entering Workchart 6 on the right side scale A at 8 decibels, we move across to the diagonal lines, finding 0.29 by interpolating between the lines marked at 0.2 and 0.5. Moving directly up to a point midway between the R lines of 50 and 70, we find our estimated R of approximately 60. Moving across to the left we find that the line of sight between the observer and the truck source height must be broken by a value of h equal to 4.5 feet.

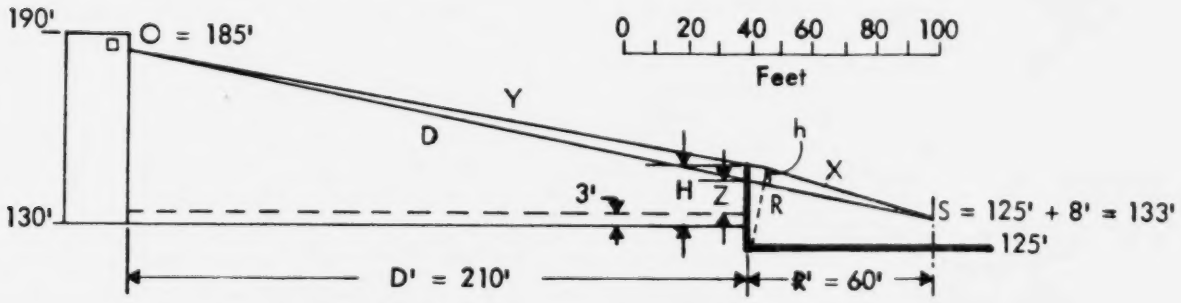


FIGURE 13. SKETCH SHOWING DIMENSIONS FOR EXAMPLE 14

We can determine the height of the wall H in several ways. By drawing h = 4.5 feet to scale on Figure 13, we can scale the total wall height H to be approximately 20 feet. Those who feel comfortable with geometry can calculate H by using the similar triangle relationships in Figure 13 to determine that H is 19.1 feet.

Now we must find how much a wall 19 feet high will attenuate automobile noise, remembering that the source height for automobiles is at the road surface elevation of 125 feet. By scaling the drawing, or by geometry, we determine that the line of sight between the observer position and the automobile source is broken by a value of h that is approximately 23.5 feet. Entering Workchart 6 at 23.5 feet we find, for R = 60 feet and R/D = 0.29, that the potential barrier attenuation is 17 dB. We must reduce this by 3 dB for loss of ground attenuation to find the actual shielding of automobile noise to be 14 dB. The original 69 dB of automobile noise is reduced to 69 - 14 = 55 dB.

Finally, we combine the heavy truck noise, attenuated by the wall to 69 - 5 = 64 dB, with the automobile noise reduced to 55 dB, to find a combined DNL of 64.5 dB, or 65 dB when rounded upward.

Railways – Worksheet D

Necessary Information

To evaluate a site's exposure to railway noise, you will need to consider all rapid transit lines and railroads within 3000 feet of the site (except totally covered subways). The information required for this evaluation is listed below under headings that indicate the most. likely source.

Before beginning the evaluation, you should record the following information on Worksheet D –

From the area map and/or the (County) Engineer:

- The distance from the appropriate NAL on the site to the center of the railway track carrying most of the traffic.

From the Supervisor of Customer Relations for the railway:

- The number of diesel and the number of electrified trains in both directions during an average 24-hour day.
- The fraction of trains that operate during nighttime (10 p.m. – 7 a.m.) If this is unknown, assume 0.15.
- The average number of diesel locomotives per train. If this is unknown, assume 2.
- The average number of railway cars per diesel train and per electrified train. If this is unknown, assume 50 for diesel trains and 8 for electrified trains.
- The average train speed. If this is unknown, assume 30 mph.
- Is the track made from welded or bolted rails?

- Is the site near a grade crossing that requires prolonged use of the train's horn or whistle?

Electrified rapid transit and commuter trains that do not use diesel engines should be treated the same as railway cars.

Note: Buildings closer than 100 feet to a railroad track are often subject to excessive vibration transmitted through the ground. Construction at such sites is discouraged.

Evaluation of Site Exposure to Railway Noise

Railway noise is produced by the combination of diesel engine noise and railway car noise. These Guidelines provide for the separate evaluation of diesel locomotives and railroad cars, and then the combination of the two, in order to obtain the DNL from trains. When rapid transit or electrified trains that do not use diesel engines are the only trains passing near a site go directly to the second part of the evaluation since these trains are treated in the same manner as railway cars.

Diesel Locomotives

Workchart 3 was derived with the following assumptions:

- A clear line of sight exists between the railway track and the Noise Assessment Location.
- There are two diesel locomotives per train.
- The average train speed is 30 mph.
- Nighttime operations are 0.15 of the 24-hour total.
- The site is not near a grade crossing requiring prolonged use of the train's horn or whistle.

If the situation meets these conditions, proceed to Workchart 3 for an immediate evaluation of diesel locomotive noise.

BUT:

If any of the conditions is different, make the necessary adjustments listed below and then use Workchart 3 for the evaluation.

Adjustments for Diesel Locomotives

Number of Locomotives:

If the average number of diesel locomotives per train is not 2, divide the average number by 2. Enter this value in column 9 of Worksheet D.

Average Train Speed:

If the average train speed is different from 30 mph, find the appropriate adjustment factor from Table 9 and list in column 10 of Worksheet D.

Table 9

Average Speed (mph)	Speed Adjustment Factor
10	3.00
20	1.50
30	1.00
40	0.75
50	0.60
60	0.50
70	0.43

Horns or Whistles:

If prolonged use of a horn or whistle is required at a grade crossing

located less than 5 times the distance from the NAL to the railway, enter the number 10 in column 11, Worksheet D.

Nighttime Adjustment:

Remember to adjust for nighttime operations if different from 0.15 of the total by selecting the appropriate adjustment factor from Table 5 on page 12. Enter in column 12, Worksheet D.

Multiply the adjustment factors together, times the number of diesel trains per day (you have listed this number previously on line 2a, page 1, of Worksheet D, and should enter this number again in column 13) to obtain the adjusted number of trains per day. Enter the adjusted number of diesel trains per day in column 14. Use this value, in conjunction with the distance from the NAL to the track (line 1, page 1, of Worksheet D) to find from Workchart 3 the DNL produced by diesel locomotives. List in column 15 of Worksheet D.

Railway Cars and Rapid Transit Systems

Workchart 4 was derived with the following assumptions:

- A clear line of sight exists between the railway and the noise assessment location.
- There are 50 cars per train.
- The average train speed is 30 mph.
- Nighttime operations are 0.15 of the 24-hour total.
- Rails are welded together.
- Horns or whistles are not used.

If The situation meets these conditions, proceed to Workchart 4 for an immediate evaluation of railway car noise. Again, if any of the conditions is different, make the necessary adjustments listed below and then use Workchart 4 for the evaluation.

Adjustments for Railway Cars and Rapid Transit Trains

Number of Cars:

Divide the average number of cars by 50 and enter this number in column 18 of Worksheet D.

Average Speed:

Make this adjustment if the average speed is not 30 mph by selecting the appropriate value from Table 10, entering it in column 19 of Worksheet D.

Table 10

Average Speed (mph)	Speed Adjustment Factor
10	0.11
20	0.44
30	1.00
40	1.78
50	2.78
60	4.00
70	5.44
80	7.11
90	9.00
100	11.11

Bolted Rails:

Enter the number 4 in column 20 of Worksheet D.

Horns and Whistles:

For trains propelled by diesel engines, adjustment for horns or whistles is already taken care of under engine noise. For electrified trains or rapid transit cars not propelled by diesel engines, enter the number 100 in column 21 of Worksheet D.

Nighttime Adjustment:

Enter the appropriate adjustment factor from Table 5 in column 22 of Worksheet D.

Example 15a: The distance from NAL #1 to Railway #1 is 339 feet. Two percent of the 35 daily operations occur at night; there is clear line of sight between the tracks and the NAL, and no horns or whistles are used. No information is available on train size or speed.

Since the percentage of nighttime operations is different from 15 percent, we must adjust the actual number of daily operations, multiplying by 0.50 according to Table 5.

$$0.50 \times 35 = 17.5 = 18$$

Entering Workchart 3 with 18 daily operations and a distance of 339 feet, we find that the contribution of diesel engine noise is a DNL of 59 dB (see Figure 14).

In order to find the total contribution of the trains to the total DNL, we must also find the noise level produced by the train's cars. Entering Workchart 4 (see Figure 15) with 18 daily operations and a distance of 339 feet, we find the DNL is below 50 on the chart, or more than 10 decibels lower than the noise level produced by the engines. From the chart for decibel addition, the combination

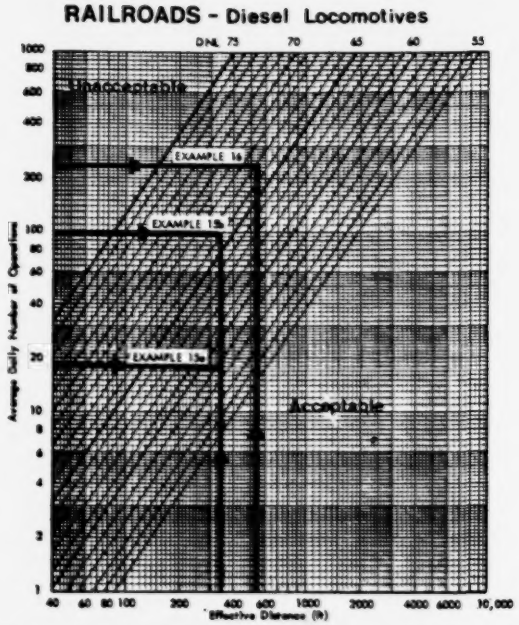


FIGURE 14. USE OF WORKCHART 3 TO EVALUATE DIESEL LOCOMOTIVE NOISE

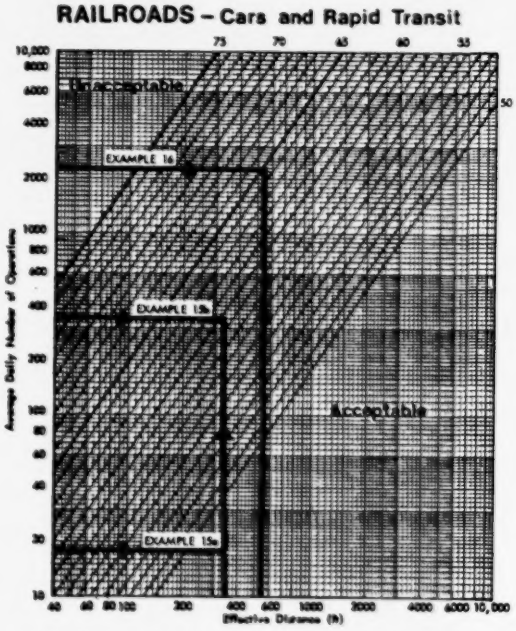


FIGURE 15. USE OF WORKCHART 4 TO EVALUATE RAILWAY CAR NOISE

of the noise from the engines and from the cars adds less than 0.5 decibels to the DNL value for the engines alone, 59 dB.

Example 15b: Suppose that a forecast of train operations for Example 15a indicates that there will still be 35 trains per day, but now 50 percent of the operations will occur at night, the average train will have 4 engines and 75 cars, and the average speed will be 50 mph.

We first find the contribution to DNL made by engines by using the following adjustment factors:

- number of engines adjustment: 2
- speed adjustment: 0.60
- day/night adjustment: 2.34

We multiply these adjustments together with the number of trains:

$$2 \times 0.60 \times 2.34 \times 35 = 98$$

Entering Workchart 3 (see Figure 14) with 98 daily operations and a distance of 339 feet, we find that the site has an engine noise contribution to DNL of 66 dB.

We next obtain the adjustment factors for the noise produced by the cars:

- number of cars adjustment: 1.50
- speed adjustment: 2.78
- day/night adjustment: 2.34

Multiplying the adjustment factors times the average daily number of trains:

$$1.5 \times 2.78 \times 2.34 \times 35 = 342$$

Entering Workchart 4 (see Figure 15) with 342 operations and a distance of 339 feet, we find the contribution of the cars to the DNL is 60 dB. Using Table 1 for combining levels, we find that the 6 dB difference between engine noise at 66 and car noise 60 gives a combined DNL of 67 dB these trains.

Example 16: The distance from NA to Railroad #2 is 550 feet; there 100 operations per day, of which percent occur at night. A clear of sight exists between the site the railroad, and no horns or whi tles are used nearby. An average train on this track uses 4 engine has 100 cars, the average speed t miles per hour, and the track has bolted, not welded, rails.

We first find the adjustment fact for the diesel engines:

- number of engines adjustment: 2
- speed adjustment: 0
- day/night adjustment: 1

Multiplying the adjustments toget times the number of trains:

$$2 \times 0.75 \times 1.57 \times 100 = 236$$

Entering Workchart 3 (see Figure with 236 operations at a distance 550 feet, we find the DNL contrib tion from engine noise to be 67 d

Next we find the adjustment facto for the railroad cars:

- number of cars adjustment: 2
- speed adjustment: 1.
- bolted track adjustment: 4
- day/night adjustment: 1.

Multiplying the adjustments toget times the number of trains:

$$2 \times 1.78 \times 4 \times 1.57 \times 100 = 223$$

Entering Workchart 4 (see Figure with 2236 operations at a distanc

550 feet, we find the DNL contribution from the railroad cars to be 65 dB. Combining the engine sound levels with the car sound levels we find the total DNL from the trains to be 69 dB.

It would be possible to erect a 20-foot noise barrier, running parallel to the track at a distance of 50 feet; it could start at Road #2 and run 900 feet north toward the airport, as shown in Figure 16. Both the railroad track and the ground level at the barrier location are at an elevation of 160 feet. Thus, we have the following values with which to enter Workchart 5. (Because the distances involved are so unequal, this situation does not lend itself to direct scaling of the distances.)

H = 180 feet (20' above the ground)

S = 175 feet (15' above the track, see page 19)

O = 285 feet (from Example 11 in the section on roadway noise)

R' = 50 feet

D' = 500 feet

We find from Worksheet 5 that the values of R and D are no different (within the accuracy of the calculation) from R' and D', a situation that will always occur when the differences in elevation are so much smaller than the distances from the site to the noise source. The value of h is 4 feet; R/D = 0.1.

We can now use these numbers to enter Workchart 6 to find the potential barrier performance (that is, the barrier adjustment factor that would apply in the case of an infinitely long barrier). Entering Workchart 6 at h = 4 feet, with R/D = 0.1, we

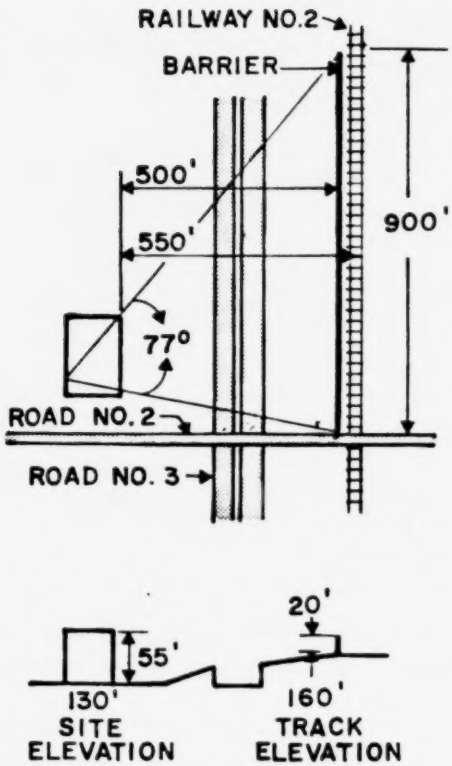


FIGURE 16. SKETCH SHOWING DIMENSIONS FOR EXAMPLE 16

find the basic attenuation of the barrier to be 7.5 dB. However, with D/R = 10, we find from the table of loss-of-ground-effect attenuation that we must subtract 4 dB from the 7.5, or a net effect of 3.5 dB. However, the situation is even worse, since the barrier is finite in length.

To find the actual attenuation for this finite barrier, we must first find the angle subtended by the barrier to the site. Referring to Figure 16, we draw lines from the dwelling unit on the site to each end of the barrier. With a protractor we measure the angle between the two lines to be 77 degrees. Locate the curve on Workchart 7 corresponding to the potential barrier attenuation of

3.5 dB; it lies midway between the two lowest curves (see Figure 18). The point on this curve corresponding to a subtended angle of 77° indicates that the actual barrier performance would be only 1.5 dB. With only 1.5 dB of attenuation, the barrier is clearly not cost-effective. In order to achieve a usable attenuation from the barrier, it would have to be extended beyond the other side of Road #2 to obtain a larger included angle. This extension, however, would also not be cost-effective unless the height of the barrier were increased substantially.

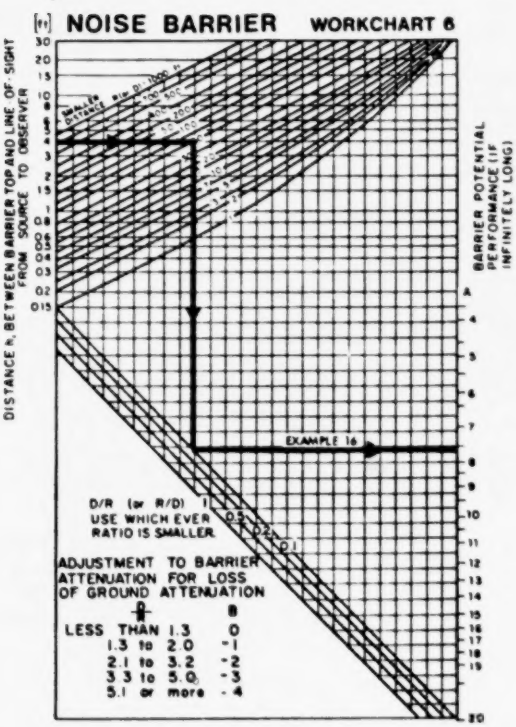
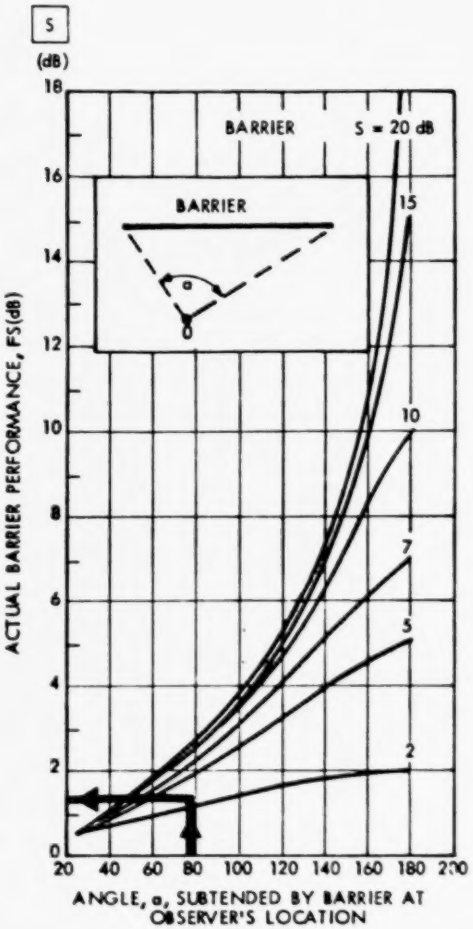

NOISE BARRIER
WORKCHART 6
DISTANCE A, BETWEEN BARRIER TOP AND LINE OF SIGHT FROM SOURCE TO OBSERVER
BARRIER POTENTIAL PERFORMANCE (IF INFINITELY LONG)
EXAMPLE 16
D/R (or R/D) USE WHICH EVER RATIO IS SMALLER
ADJUSTMENT TO BARRIER ATTENUATION FOR LOSS OF GROUND ATTENUATION
LESS THAN 1.3 0
1.3 to 2.0 -1
2.1 to 3.2 -2
3.3 to 5.0 -3
5.1 or more -4

FIGURE 17. USE OF WORKCHART 6 IN EXAMPLE 16



Correction to be applied to barrier potential in order to find the actual performance of the barrier of some construction but of finite length.

FIGURE 18. USE OF WORKCHART 6 IN EXAMPLE 16

Walk-Away Test – Worksheet E

Necessary Information

The Walk-Away Test is an optional evaluation that may be performed during any visit to the site. It is a useful tool for obtaining an approximate idea of the DNL at a site where aircraft and railway noise are not prominent. That is, the Walk-Away Test is suggested as a means for assessing the cumulative effects of noise from various sources at the time the test is performed. It is not to be used to determine the acceptability of the noise environment at a site, but merely to indicate the likelihood that a site may be acceptable if the noise at the time of the test is representative of the calculated DNL over a 24-hour period.

The Walk-Away Test has been designed to estimate—without reference to specific sources—the overall noise condition at a site by determining the distance over which one person can just understand the speech of another. Since noise may vary during a 24-hour period, this test should be performed during the peak morning and afternoon traffic periods. The noise at these times is closely equal, numerically, to the DNL over 24 hours.

When performing a Walk-Away Test, you should record the following information on Worksheet E -

- The date and time of the visit to the site.

- The average distance where understanding just becomes difficult

Estimated DNL at a Site

The Walk-Away Test requires two people who exchange roles as speaker and listener; thus, each person should have normal hearing and an average voice. To perform the test, you will need a 100-foot tape measure and some reading material with which both persons are unfamiliar.

The speaker should stand at one location while the listener, starting at a distance of 2 or 3 feet, backs away still facing the speaker. The speaker should hold the reading material at chest height in such a way as not to block the direct path to the listener. The speaker should not use a raised voice in an attempt to maintain communication.

At some point the listener will understand only a scattered word or two over a period of 10 seconds or more. At this point, measure the distance between the listener and the speaker.

To improve consistency and accuracy, this procedure should be repeated several times during each visit and the distances should be averaged. Also, the roles of speaker and listener should be reversed to average out variations of normal speaking levels and hearing acuity. After each visit, evaluate the site's overall noise levels by using the following table:

ESTIMATED DNL AT A SITE WHERE INDIVIDUAL NOISE EVENTS ARE NOT PREDOMINANT

Distance Where Understanding Becomes Very Difficult	Approximate DNL Range
More than 25 feet	Less than 65 dB
7 to 25 feet	65 to 75 dB
Less than 7 feet	More than 75 dB

References

1. D. E. Bishop, A. P. Hays, "Handbook for Developing Noise Exposure Contours for General Aviation Airports," FAA-AS-75-1, December 1975 (NTIS No. AD-A023429).

2. D. E. Bishop, et. al., "Calculation of Day-Night Levels Resulting From Civil Aircraft Operations, " BBN Report 3157 for Environmental Protection Agency, March 1976 (NTIS No. PB 266 165).

3. B. A. Kugler, D. E. Commins, W. J. Galloway, "Highway Noise - A Design Guide For Prediction and Control," NCHRP Report 174, Transportation Research Board, National Research Council, 1976.

4. T. J. Schultz, W. J. Galloway, "Noise Assessment Guidelines - Technical Background," Office of Policy Development and Research, Department of Housing and Urban Development," _____ 1979.

5. M. A. Simpson, "Noise Barrier Design Handbook," FHWA-RD-76-58, Federal Highway Administration, February 1976 (NTIS No. PB 266 378).

Summary of Adjustment Factors

Combination of Sound Levels

Table 1

Difference in Sound Level	Add to Larger Level
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
12	0.3
14	0.2
16	0.1
greater than 16	0

Aircraft

- DNL Outside 65 dB Contour

  D_1 = distance from 65 dB contour to flight path

  D_2 = distance from site to flight path

Table 2

$\frac{D_2}{D_1}$	DNL dB
1.0	65
1.12	64
1.26	63
1.41	62
1.58	61
1.78	60
2.00	59
2.24	58
2.51	57
2.82	56
3.16	55

Automobile Traffic

- Stop-and-go

Table 3

Distance from Site to Stop Sign feet	Automobile Stop-and-go Adjustment Factor
0	0.10
100	0.25
200	0.40
300	0.55
400	0.70
500	0.85
600	1.00

- Average Traffic Speed

Table 4

Average Traffic Speed	Adjustment Factor
20 (mph)	0.13
25	0.21
30	0.30
35	0.40
40	0.53
45	0.67
50	0.83
55	1.00
60	1.19
65	1.40
70	1.62

- Nighttime (applies to all sources)

Table 5

Nighttime Fraction of ADT	Nighttime Adjustment Factor
0	0.43
0.01	0.46
0.02	0.50
0.05	0.62
0.10	0.81
0.15	1.00
0.20	1.19
0.25	1.38
0.30	1.57
0.35	1.78
0.40	1.96
0.45	2.15
0.50	2.34

Medium Trucks

(less than 26,000 pounds, greater than 10,000 pounds)

Multiply adjusted automobile traffic by 10.

Heavy Trucks

- Road Gradient

Table 6

Percent of Gradient	Adjustment Factor
2	1.4
3	1.7
4	2.0
5	2.2
6 or more	2.5

- Average Speed

Table 7

Average Traffic Speed (mph)	Truck Speed Adjustment Factor
50 or less	0.81
55	1.00
60	1.17
65	1.38

- Stop-and-Go

Table 8

Heavy Truck Traffic Volume per Day	Heavy Truck Stop-and-Go Adjustment Factor
Less than 1200	1.8
1201 to 2400	2.0
2401 to 4800	2.3
4801 to 9600	2.8
9601 to 19,200	3.8
More than 19,200	4.5

Railroads - Diesel Engines

- Number of Engines per Train

  The number of engines divided by 2.

- Average Train Speed

Table 9

Average Speed (mph)	Speed Adjustment Factor
10	3.00
20	1.50
30	1.00
40	0.75
50	0.60
60	0.60
70	0.43

- Whistles or horns

  Multiply number of trains by 10.

Railroads - Cars and Rapid Transit

- Number of cars.

  Number of cars per train divided by 50.

- Average Train Speed

Table 10

Average Speed (mph)	Speed Adjustment Factor
10	0.11
20	0.44
30	1.00
40	1.78
50	2.78
60	4.00
70	5.44
80	7.11
90	9.00
100	11.11

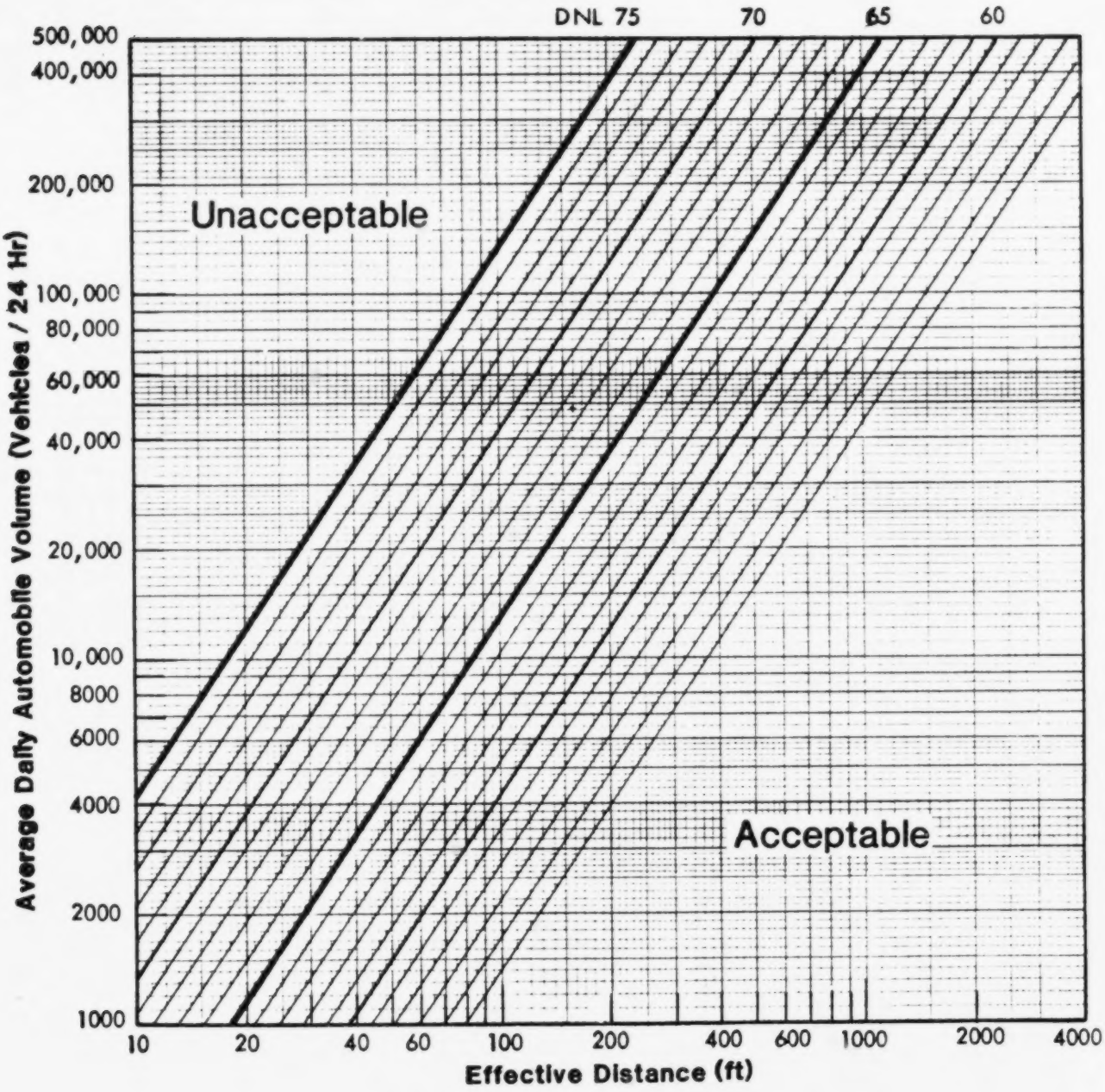
- Bolted Rails

  Multiply number of trains by 4.

- Whistles or Horns

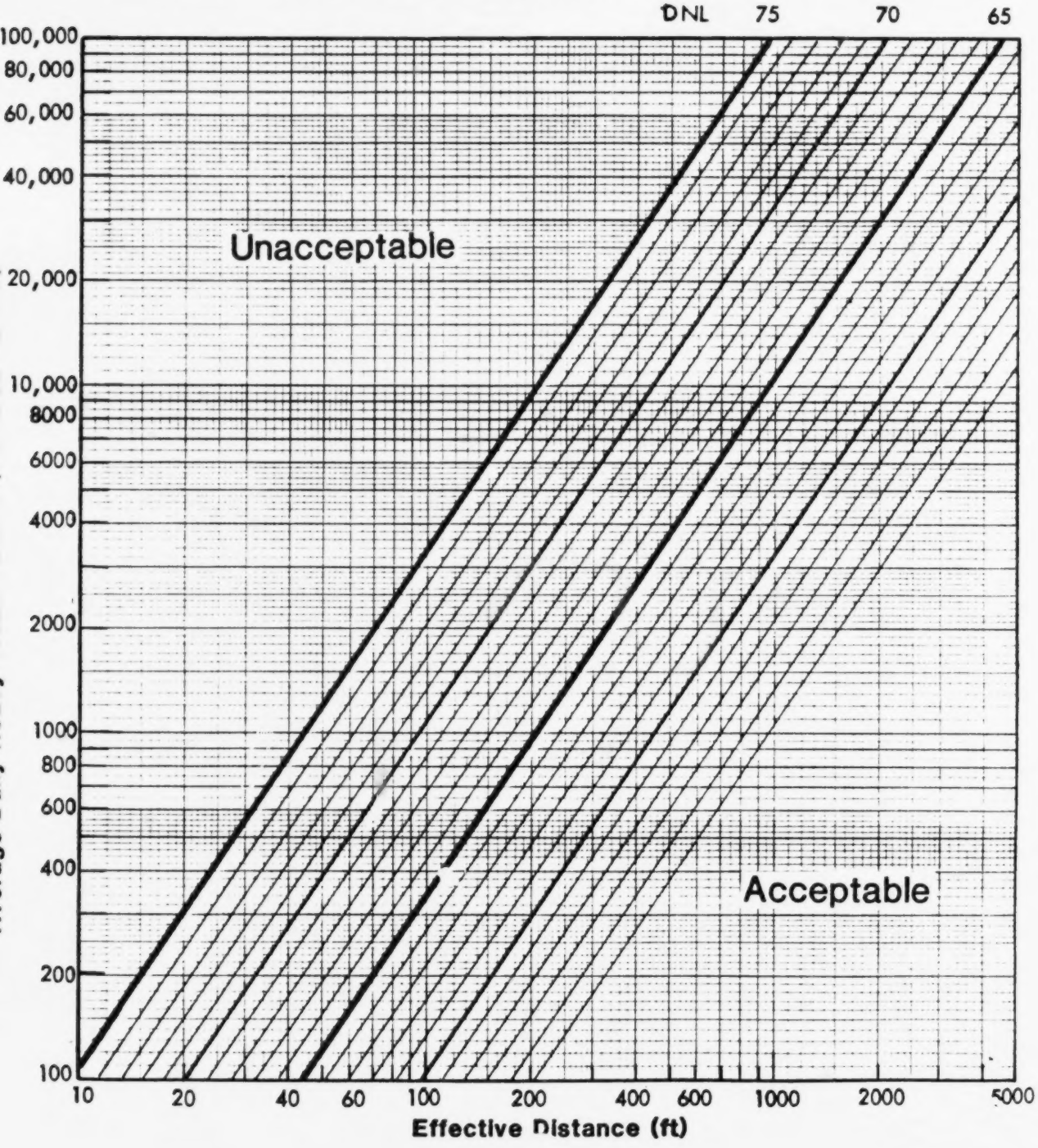
  Multiply number of trains by 100.

AUTOS (55mph)



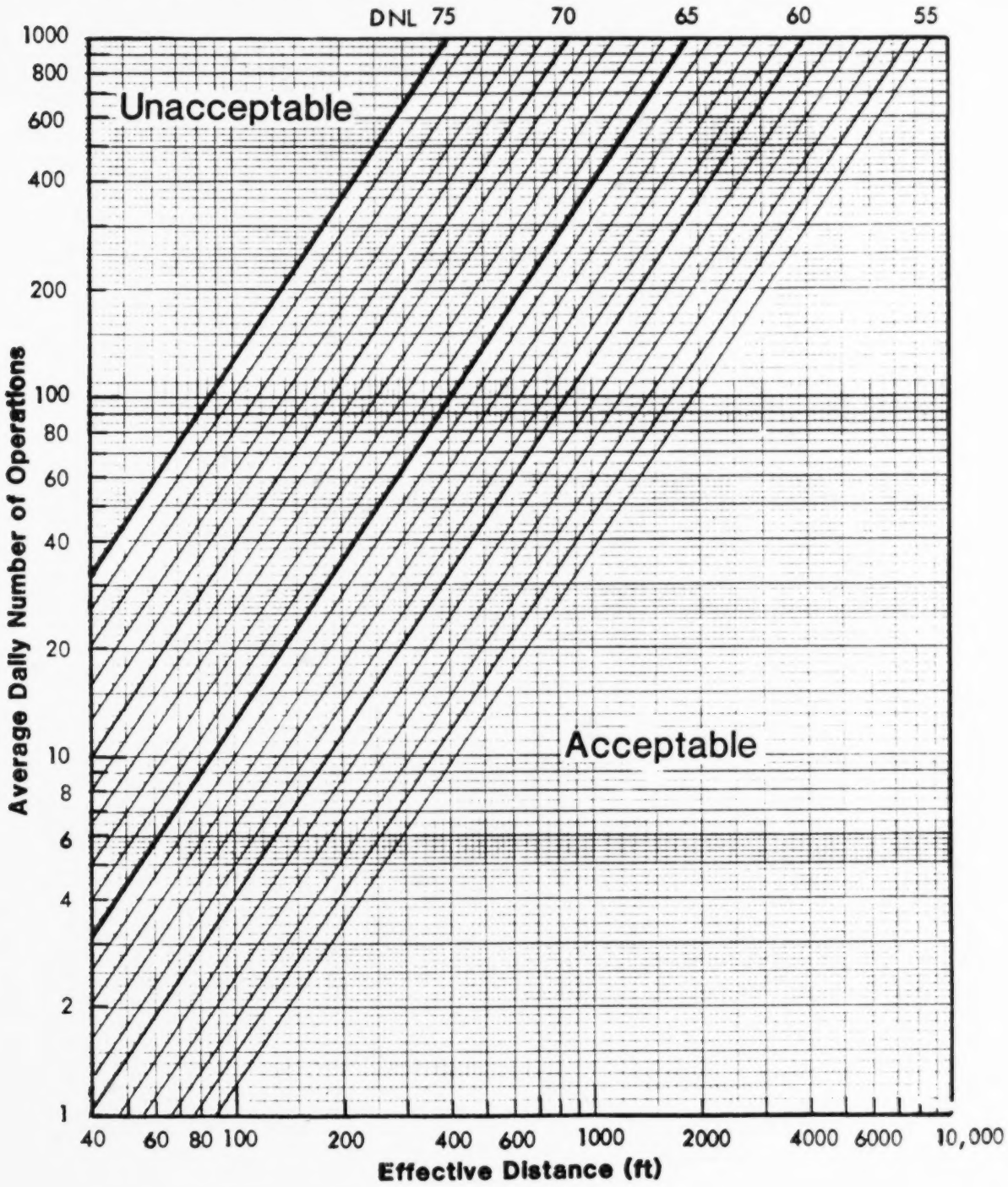
WORKCHART 1

HEAVY TRUCKS (55mph)



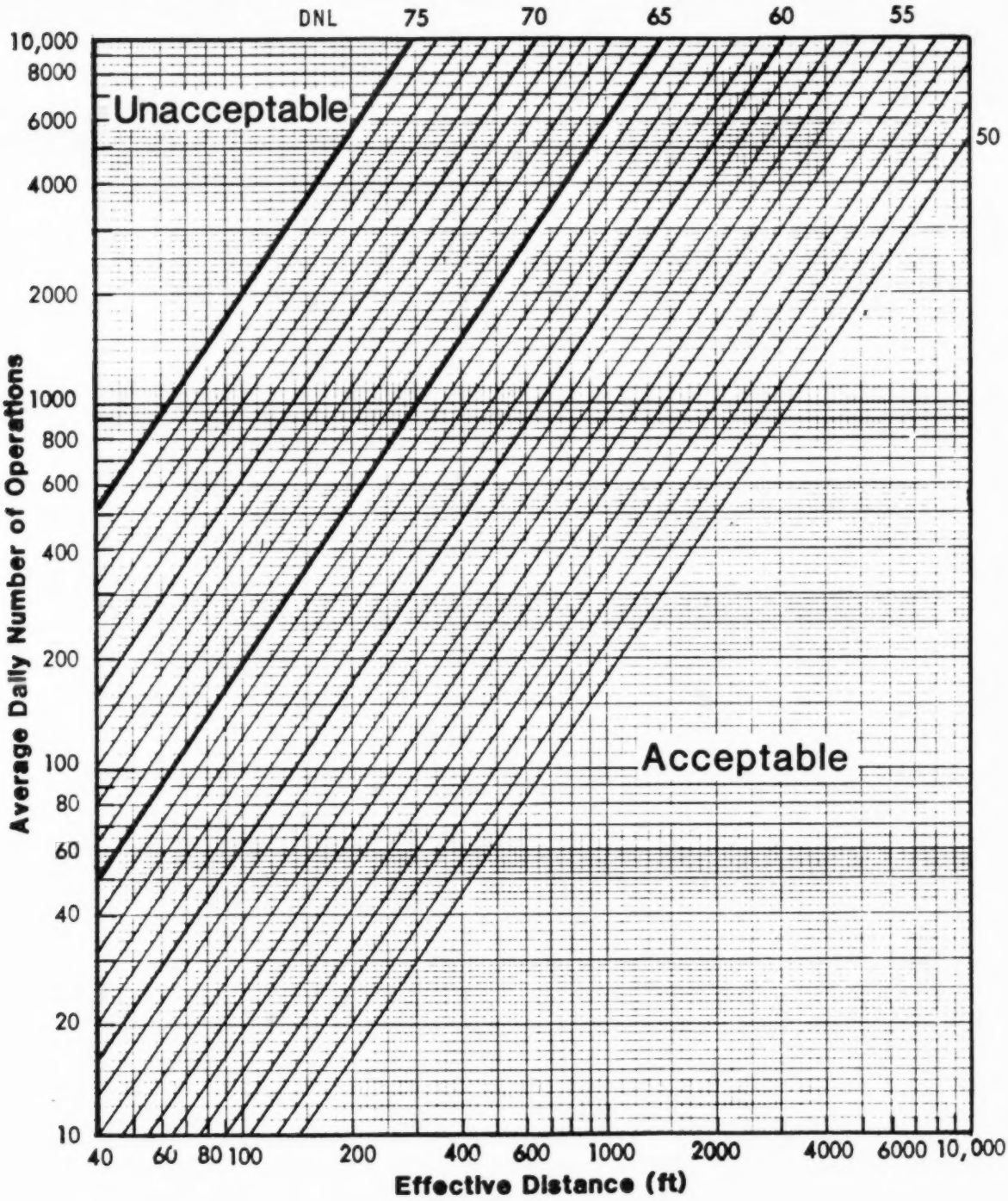
WORKCHART 2

RAILROADS - Diesel Locomotives



WORKCHART 3

RAILROADS - Cars and Rapid Transit

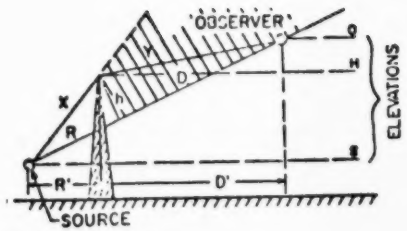


WORKCHART 4

NOISE BARRIER

WORKCHART 5

TO FIND R, D AND h FROM SITE ELEVATIONS AND DISTANCES



Enter the values for:

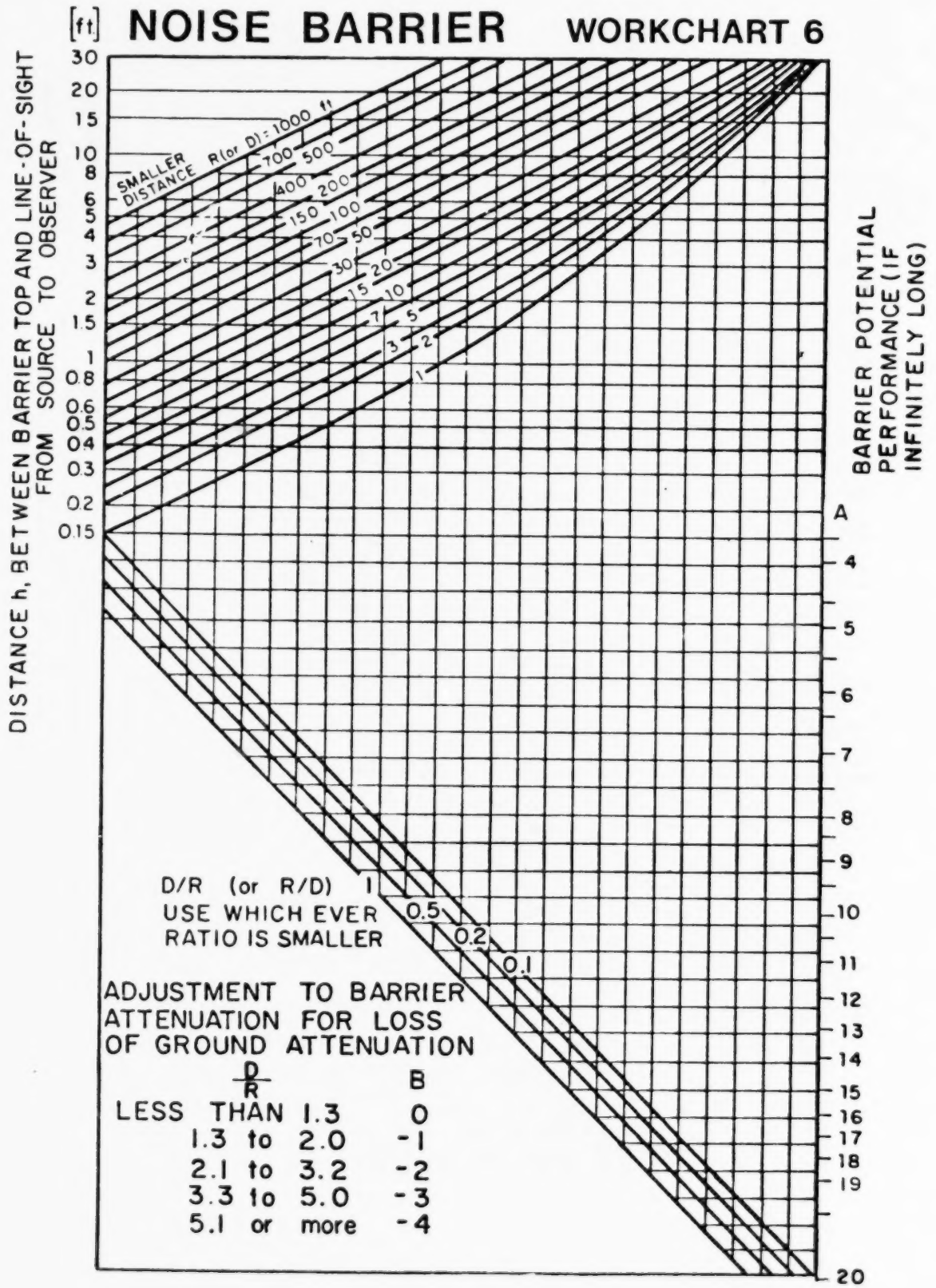
H = _____ R' = _____
S = _____ D' = _____
O = _____

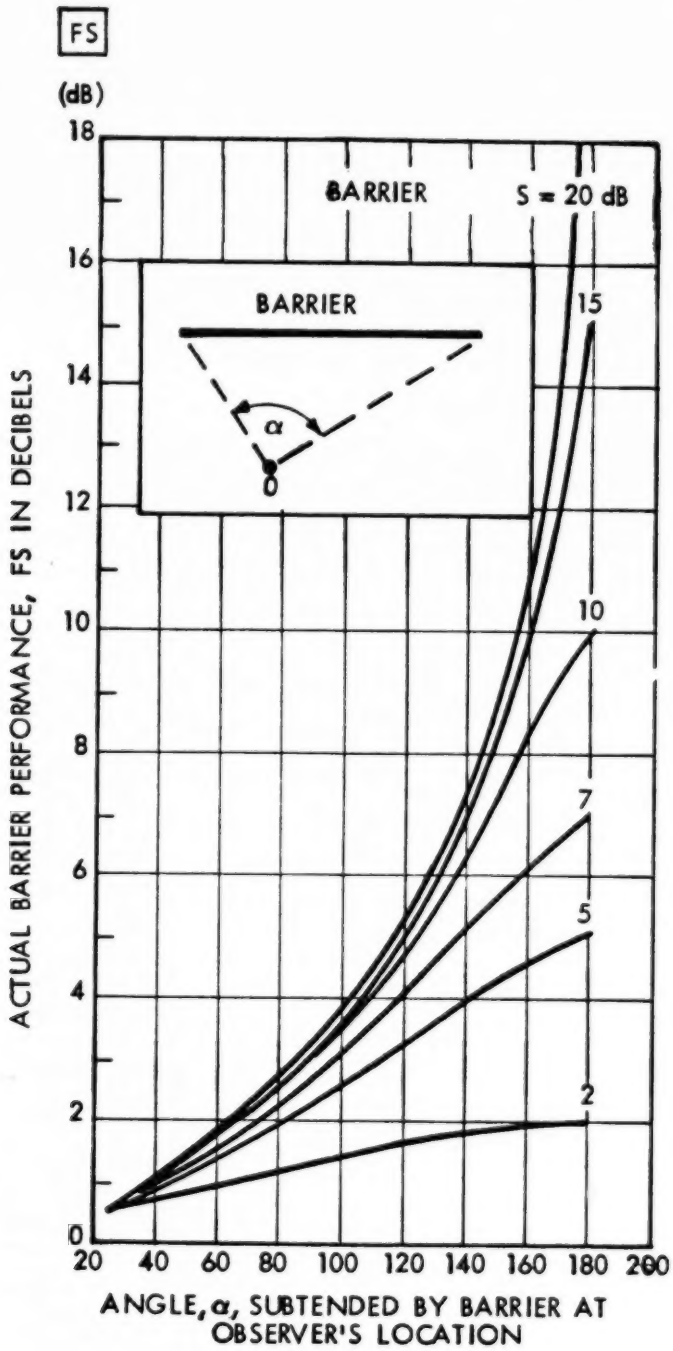
Fill out the following worksheet (all quantities are in feet):

1.	Elevation of barrier top minus elevation of source	[11]	−	[8]	=	[1]		
2.	Elevation of observer minus elevation of source	[o]	−	[8]	=	[2]		
3.	Map distance between source and observer (R' + D')					[3]		
4.	Map distance between barrier and source (R')					[4]		
5.	Line 2 divided by line 3	[2]	÷	[3]	=	[5]		
6.	Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5]	×	[5]	=	[6]		
7.	40% of line 6	[0.4]	×	[6]	=	[7]		
8.	One minus line 7	[1.0]	−	[7]	=	[8]		
9.	Line 5 times line 4 (will be negative if line 2 is negative)	[5]	×	[4]	=	[9]		
10.	Line 1 minus line 9	[1]	−	[9]	=	[10]		
11.	Line 10 times line 8	[10]	×	[8]	=	[11]	= h	
12.	Line 5 times line 10	[5]	×	[10]	=	[12]		
13.	Line 4 divided by line 8	[4]	÷	[8]	=	[13]		
14.	Line 13 plus line 12	[13]	+	[12]	=	[14]	= R	
15.	Line 3 minus line 4	[3]	−	[4]	=	[15]		
16.	Line 15 divided by line 8	[15]	÷	[8]	=	[16]		
17.	Line 16 minus line 12	[16]	−	[12]	=	[17]	= D	

[Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: X + (−Y) = X − Y. And subtracting a negative number is like adding: X − (−Y) = X + Y.]

Round off R and D to nearest integer, h to one decimal place.


[ft] NOISE BARRIER WORKCHART 6
DISTANCE h, BETWEEN BARRIER TOP AND LINE-OF-SIGHT FROM SOURCE TO OBSERVER
30
20
15
10
8
6
5
4
3
2
1.5
1
0.8
0.6
0.5
0.4
0.3
0.2
0.15
SMALLER DISTANCE R(or D) = 1000 ft
700
500
400
200
150
100
70
50
30
20
15
10
7
5
3
2
1
BARRIER POTENTIAL PERFORMANCE (IF INFINITELY LONG)
A
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
D/R (or R/D) 1
USE WHICH EVER RATIO IS SMALLER
0.5
0.2
0.1
ADJUSTMENT TO BARRIER ATTENUATION FOR LOSS OF GROUND ATTENUATION
D/R B
LESS THAN 1.3 0
1.3 to 2.0 -1
2.1 to 3.2 -2
3.3 to 5.0 -3
5.1 or more -4



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

WORKCHART 7

WORKSHEET A - Site Evaluation

Site Location: _____

Program _____

Project Name _____

Locality _____

File Number _____

Sponsor's Name _____

Street Address _____

City, State _____

Phone _____

	Acceptability Category:	DNL	Predicted for Operations in Year
1. Roadway Noise	_____	_____	_____
2. Aircraft Noise	_____	_____	_____
3. Railway Noise	_____	_____	_____

Final Site Evaluation (circle one)

ACCEPTABLE

NORMALLY UNACCEPTABLE

UNACCEPTABLE

Value of DNL for all noise sources:
(see page 3 for combination procedure)

_____

Clip this worksheet to the top of a package containing Worksheets B-E and Workcharts 1-7 that are used in the site evaluations

Date: _____

Signature _____

WORKSHEET B - Aircraft Noise

List all airports within 15 miles of the site:

1. _____
2. _____
3. _____

Necessary Information:	Airport #1	Airport #2	Airport #3
1. Are DNL, NEF or CNR contours available? (yes/no)			
2. Any supersonic aircraft operations? (yes/no)			
3. Estimating approximate contours from Figure 3:			
a. number of nighttime jet operations			
b. number of daytime jet operations			
c. effective number of operations (10 times a + b)			
d. distance A for 65 dB			
70 dB			
75 dB			
e. distance B for 65 dB			
70 dB			
75 dB			
4. Estimating DNL from Table 2:			
a. distance from 65 dB contour to flight path, D_1			
b. distance from NAL to flight path, D_2			
c. D_2 divided by D_1			
d. DNL			
5. Operations projected for what year?			
6. Total DNL from all airports			

Date _____

Signed _____

WORKSHEET C - Roadway Noise - Page 1

List all major roads within 1000 ft of the site:

1. _____
2. _____
3. _____
4. _____

Necessary Information	Road #1	Road #2	Road #3	Road #4
1. Distance in feet from the NAL to the edge of the road				
a. nearest lane				
b. farthest lane				
c. average (effective distance)				
2. Distance to stop sign				
3. Road gradient in percent				
4. Average speed in mph				
a. automobiles				
b. heavy trucks - uphill				
c. heavy trucks - downhill				
5. 24 hour average number of automobiles and medium trucks in both directions (ADT)				
a. automobiles				
b. medium trucks				
c. effective ADT (a + (10 x b))				
6. 24 hour average number of heavy trucks				
a. uphill				
b. downhill				
c. total				
7. Fraction of nighttime traffic (10:00 p.m. to 7:00 a.m.)				
8. Traffic projected for what year?				

ADJUSTMENTS FOR AUTOMOBILE TRAFFIC

	9 Stop and-go Table 3		10 Average Speed Table 4		11 Night-time Table 5		12 Auto ADT (line 5c)		13 Adjusted Auto ADT		14 DNL (Workchart) 1		15 Barrier Atten-uation		16 Partial DNL
Road #1	___	x	___	x	___	x	_____	=	_____		___	-	___	=	_____
Road #2	___	x	___	x	___	x	_____	=	_____		___	-	___	=	_____
Road #3	___	x	___	x	___	x	_____	=	_____		___	-	___	=	_____
Road #4	___	x	___	x	___	x	_____	=	_____		___	-	___	=	_____

ADJUSTMENTS FOR HEAVY TRUCK TRAFFIC

	17 Gradient Table 6		18 Average Speed Table 7		19 Truck ADT / 2		20	21	22 Stop and-go Table 8		23 Night-time Table 5		24 Adjusted Truck ADT		25 DNL (Work chart 2)		26 Barrier Attn.		27 Partial DNL
Uphill Road #1	___	x	___	x	___	=	___												
Downhill			___	x	___	=	___	Add___	x ___	x	___	=	_____		___	-	___	=	_____
Uphill Road #2	___	x	___	x	___	=	___												
Downhill			___	x	___	=	___	Add___	x ___	x	___	=	_____		___	-	___	=	_____
Uphill Road #3	___	x	___	x	___	=	___												
Downhill			___	x	___	=	___	Add___	x ___	x	___	=	_____		___	-	___	=	_____
Uphill Road #4	___	x	___	x	___	=	___												
Downhill			___	x	___	=	___	Add___	x ___	x	___	=	_____		___	-	___	=	_____

Combined Automobile & Heavy Truck DNL

Road #1_____ Road #2 _____

Road #3_____ Road #4_____

Total DNL for All Roads _____

Date_____

Signature_____

WORKSHEET D - Railway Noise - Page 1

List all railways within 3000 feet of the site:

1. _____

2. _____

3. _____

Necessary Information:	Railway #1	Railway #2	Railway #3
1. Distance in feet from the NAL to the railway track:			
2. Number of trains in 24 hours:			
a. diesel			
b. electrified			
3. Fraction of operations occurring at night (10 p.m. - 7 a.m.):			
4. Number of diesel locomotives:			
5. Number of rail cars:			
a. diesel trains			
b. electrified trains			
6. Average train speed:			
7. Is track welded or bolted?			
8. Are whistles or horns required for grade crossings?			

ADJUSTMENTS FOR DIESEL LOCOMOTIVES

	9 No. of Locomotives 2		10 Average Speed Table 9		11 Horns (enter 10)		12 Night-time Table 5		13 No. of Trains (line 2a)		14 Adj. No. of Opns.		15 DNL Workchart 3		16 Barrier Attn.		17 Partial DNL
ilway #1	____	x	____	x	____	x	____	x	____	=	_____		____	-	____	=	_____
ilway #2	____	x	____	x	____	x	____	x	____	=	_____		____	-	____	=	_____
ilway #3	____	x	____	x	____	x	____	x	____	=	_____		____	-	____		____

ADJUSTMENTS FOR RAILWAY CARS OR RAPID TRANSIT TRAINS

	18 Number of cars 50		19 Average Speed Table 10		20 Bolted Rails (enter 4)		21 Horns Electrified Trains Only (enter 100)		22 Night-time Table 5		23 No. of Trains (Line 2a or 2b)		24 Adj. No. of Opns.		25 DNL Work-chart 4		26 Barrier Attn.		27 Partial DNL
ay #1	____	x	____	x	____	x	____	x	____	x	____	=	_____		____	-	____	=	_____
ay #2	____	x	____	x	____	x	____	x	____	x	____	=	_____		____	-	____	=	_____
ay #3	____	x	____	x	____	x	____	x	____	x	____	=	_____		____	-	____	=	_____

ned Locomotive and Railway Car DNL

ay #1 _____

ay #2 _____

ay #3 _____

Total DNL for all Railways _____

Date: _____

Signature: _____

WORKSHEET E - Walk-Away Test

Date and time of each visit to the site:

1. _____

2. _____

3. _____

	Test 1	Test 2	Test 3	Test 4	Average Distance	Estimated DNL
Visit #1						
Distance	_____	_____	_____	_____	_____	_____
Visit #2						
Distance	_____	_____	_____	_____	_____	_____
Visit #3						
Distance	_____	_____	_____	_____	_____	_____

Date: _____

Signature: _____

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